MAINE ATLANTIC SALMON CONSERVATION PLAN
REPORT ON INSTREAM FLOW STUDIES

VOLUME I
PLEASANT RIVER

APRIL 1999

Prepared by

KLEINSCHMIDT ASSOCIATES
Consulting Engineers, Scientists and Planners
Pittsfield, Maine

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MAINE ATLANTIC SALMON CONSERVATION PLAN
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1.0 INTRODUCTION

Maine is the only state in the United States still harboring native, wild stocks of Atlantic salmon *(Salmo salar).* In recent years, the decline in North American stocks of Atlantic salmon, including those of Maine have increased concerns pertaining to habitat and population protection as part of the effort to restore this species.

As part of the response to this concern, the Atlantic Salmon Conservation Plan (Plan) was prepared by the Maine Atlantic Salmon task force and released in March 1997. The task force was comprised of representatives of various state, federal and Native American agencies, conservation groups, and industry. The stated goal of the plan is *"to protect salmon and its habitat"* within the jurisdiction of the state of Maine. Implementing the Plan is the responsibility of the Land and Water Resources Council (LWRC), within the Executive Department of Maine government.

The plan contains a wide range of initiatives, including several focusing on habitat protection. Among the potential threats to salmon habitat identified in the Plan are those posed by changes to flow regime resulting from diversion or withdrawal of water. The Plan's Proposed Action for Enhanced Protection calls for the development and implementation *"of a Total Water Use Management Plan for each watershed, with the goal of meeting the needs of both Atlantic salmon and agricultural production"*. The Water Use Plan will be developed for each river basin by a Water Use Planning Committee, comprised of stakeholders and technical advisors. According to the Plan, the objective of the water use management plan is to:

"a) account for Atlantic salmon water needs on the Pleasant, Narraguagus and Machias Rivers", and

b) assess stream flow at significant habitat sites during dry periods…and determine in-stream flow based on Atlantic salmon needs for rivers with irrigation or potential for irrigation"

A Flow Team, comprised of representatives with expertise in instream flow protection and hydrology was formed. Among the team's activities was the design of studies and development of technical information necessary to form water use plans meeting the above objectives. Agencies represented include U.S. Fish and Wildlife Service, U.S. Geological Survey, Maine Atlantic Salmon Authority, Maine Department of Inland Fish and Wildlife, Maine Department of Environmental Protection, and Maine Geological Survey.

Presently, water withdrawals are annually required in the Pleasant, Narraguagus and Machias river basins during the summer season to provide irrigation for blueberry and cranberry agriculture, two key industries located within the watersheds subject to the Plan. This demand may compete with flows required to maintain adequate rearing habitat area for the early lifestages of native Atlantic salmon. The LWRC and local stakeholders recognized that the timing and magnitude of these withdrawals may reduce Atlantic salmon habitat, especially for juvenile lifestages, young-of-year (YOY) and juvenile (*parr*). As a result habitat-based flow recommendations for summer months were identified as a factor in developing the water use plan. Thus, these withdrawals may potentially affect salmon populations.

To facilitate water withdrawal permitting, the LWRC set an interim hydrologic standard based on the median unregulated flow estimated for the point of withdrawal, derived from available basin gaging and drainage area data. This approach was not based on specific habitat requirements of Atlantic salmon in Plan rivers. Thus, its ability to conserve salmon habitat was not known. The Flow Team and LWRC therefore concluded that a) a water use plan should include more refined, site-specific data on habitat, and b) an Instream Flow Incremental Methodology (IFIM) study would be the most appropriate way to gather and evaluate habitat information. Additional analysis of hydrology were also identified as required.

The IFIM was developed by the Instream Flow and Aquatic Systems Group of the U.S. Fish and Wildlife Service (now a branch of the USGS), and is a nationally recognized method used to solve competing instream water uses involving aquatic habitat. The IFIM is a tool that provides decision-makers with information showing the degree of habitat available in a defined river reach, across a range of flows (Bovee 1982). It does this by developing a quantitative estimate of habitat area selected discharges, from site-specific measurements of stream morphology, cover, substrate, depth, velocity and discharge gathered in reaches along the river. These physical measurements are then rated for habitat suitability, based on objective habitat use data developed for the aquatic species and life stages of concern. All such inputs are pre-determined by prior to conducting field work. IFIM studies have been used to evaluate and resolve salmonid habitat and flow issues in Maine, and throughout New England.

The IFIM does not compute a single “answer”, but instead estimates the extent of habitat available under existing and alternative flow scenarios. In this application, it may be used to estimate the extent that various water withdrawal proposals may affect availability of Atlantic salmon habitat in particular stream reaches within the water use plan. IFIM results must be evaluated in the context of natural hydrologic conditions in the river and the timing of proposed withdrawls.

The objective of this study is to quantitatively estimate the effects of a range of flows from approximately 7Q10 up to approximately April median flow on representative Atlantic salmon habitat for the mainstream of the Pleasant River. A 7Q10 flow represents the 7-day lowest flow likely to occur at 10-year intervals, and is frequently used in planning and permitting to characterize a “typical” drought flow for a given period. These data, along with hydrologic estimates developed independently for the LWRC by the U.S. Army Corps of Engineers will be used by the Water Use Management Plan Committee (WUMP) to develop reach-specific flow recommendations that are protective of Atlantic salmon, and address competing water withdrawals.

This IFIM study was scoped and directed by a study team comprising representatives from the Flow Team and the Maine State Planning Office. The study was conducted by Kleinschmidt Associates (KA), of Pittsfield, Maine, under the supervision of the Flow Team, and with the assistance of Cherryfield Foods, Jasper Wyman and Sons, Inc., the Pleasant River Watershed Council, and the Downeast Salmon Federation.

2.0 DESCRIPTION OF THE STUDY AREA

The following description of the Pleasant River and related fisheries resources is primarily based upon personal communication from Maine Atlantic Salmon Authority (MASA, formerly the Maine Atlantic Sea Run Salmon Commission) staff, and the following MASA documents:

1. The Pleasant River – An Atlantic Salmon River Management Report (Dube and Jordan, 1982),
2. Maine Atlantic Salmon Management Plan with Recommendations Pertaining to Staffing and Budget Matters (Baum, 1997), and
3. 1997 Endangered Species Project Report (Baum, et. al., 1998).

2.1 Pleasant River

The Pleasant River is located in the eastern coastal river basin of Washington County, Maine. The Pleasant River drains an area of 85 square miles (Dube and Jordan, 1982) and originates at Pleasant River Lake in Beddington, Maine at an elevation of 317 feet above sea level (Figure 1). The river flows southeasterly for 28 miles to the head of tide in the town of Columbia Falls, Maine. Below Columbia Falls, the Pleasant River is estuarial and meanders through salt mash areas. There are few lakes in the drainage. The headwater Pleasant River Lake (949 acres) accounts for nearly 75% of the total lake and pond area of 1,270 acres. Tributaries, arising from springs and bogs, occur as a network of small feeder streams that total 68 miles in length. Significant tributaries include Taylor Branch, Ingersoll Branch, Colonel Brook, Bog Stream and the Little River. The average gradient of the Pleasant River is slightly less than 11 feet per mile.

Topography of the Pleasant River headwaters is characterized by hills and ridges largely forested by hardwoods and spruce-fir mixtures. Drum and kettle topography produced by the melting ice and debris of the last glacier are common in the lower portions of the drainage. The lower drainage areas of the Pleasant River also contain extensive barrens and peat bogs. The Great Heath, the largest (6,000 acre) undisturbed raised bog and peatland in Maine, is located within the lower drainage areas of the Pleasant River (MDOC, 1982).

The soils of the upper two-thirds of the watershed are predominantly barrens type soils developed from glacial till along with forest podzols in timberland areas. The soils of the barrens are deep, well drained, sandy and gravelly soils which exhibit rapid permeability and function as aquifers filing up during rains and discharging over long periods of time (Prescott, 1974, *cited in* Dube and Jordan, 1982). The lower one-third of the Pleasant River watershed contains glacial till origin soils. Marine clay soils are also common in the lower drainage in areas less than 200 ft in elevation. Bedrock formations in the Pleasant River watershed are varied consisting of granite, diorite, gabbro, slate, quartzite, metasandstone, and shale phyllite with schist (Prescott, 1974, *cited in* Dube and Jordan, 1982).

2.2 Fishery Management and Habitat Use

Freshwater fisheries in the Pleasant River are managed by the Maine Department of Inland Fisheries and Wildlife (MDIFW). The Pleasant River is managed for wild populations of brook trout and provides an excellent fishery (personal communication, Ron Brokaw, Regional Fisheries Biologist, MDIFW, January 11, 1999). The majority of trout spawning and rearing, however, occurs in the tributaries to the Pleasant River rather than in the mainstem. Smallmouth bass are also managed as a secondary sport fishery in the Pleasant River. Other freshwater fish species found in the Pleasant River basin include landlocked Atlantic salmon, redbreast and pumkinseed sunfish, brown bullhead, white sucker, chain pickerel, and various minnow species. MDIFW has adopted fishing rules (for species other than Atlantic salmon) requiring a season July 1 to Sept. 1, artificial lures only, a minimum length limit on trout of 8", and a maximum size allowed on landlocked salmon of 25", and no bag limit on pickerel.

The entire length of the mainstem Pleasant River is available to most anadromous fish species for migration, spawning, and rearing of juveniles. The anadromous fish resources of the Pleasant River include Atlantic salmon, alewives, blueback herring, and rainbow smelt. American shad are occasionally present in the river, but the magnitude of the run is not known. Sea lampreys are abundant in the lower reaches of the drainage and the catadromous American eel occurs throughout the watershed. The Maine Department of Marine Resources (MDMR) is responsible for managing the estuarial and marine resources of the Pleasant River drainage. Fisheries in these waters include; mackerel and striped bass.

The MASA was formed by the Maine Legislature in September 1995, replacing the Atlantic Sea Run Salmon Commission. The statewide goal of the MASA is to protect, conserve, restore, manage, and enhance Atlantic salmon habitat, populations, and fisheries within the historical habitat in Maine. The MASA has sole authority and responsibility to manage the anadromous (sea-run) Atlantic salmon fishery in the state of Maine including the sole authority to regulate the introduction Atlantic salmon into Maine inland waters. The MASA also has sole authority to limit or prohibit the harvest of Atlantic salmon, issue licenses for the taking of Atlantic salmon and adopt rules establishing the time, place and manner of Atlantic salmon fishing in all waters of Maine.

The MASA has identified the Pleasant River as one of seven rivers in the state of Maine with the highest priority for the restoration of Atlantic salmon (Baum, et. al., 1998). Current management objectives for the Pleasant River include:

1. Restore self-sustaining runs of Atlantic salmon, increase natural reproduction of existing salmon populations,
2. Provide recreational angling opportunities and compatible non-consumptive uses, improve fish passage at natural and artificial barriers,
3. Establish partnerships that benefit restoration and management programs, and
4. Increase public awareness and broaden support for the overall restoration and management goals.

The potential for any river to produce Atlantic salmon is limited by the habitat available during the riverine stages of the salmon's life cycle (Dube and Jordan 1982). A salmon river must have adequate spawning habitat, ready access to these areas, suitable nursery areas for juvenile salmon, and holding pools for the adults. Based on existing Atlantic salmon habitat surveys for the Pleasant River and its tributaries, the minimum biologically acceptable number of spawners is 81 (Horton et. al 1998).

Historic salmon returns as estimated from sport harvest and spawning surveys indicate that current returns of Atlantic salmon to the Pleasant River are well below minimum biologically acceptable spawning escapement levels. Plans to operate a weir in the lower river beginning in the year 2000 will allow the exclusion of aquaculture escapees from nearby sea cages as well as the ability to more accurately monitor escapement of wild salmon.

The MASA 10-year restoration goal for the Pleasant River is to increase the average annual return of Atlantic salmon to 72 adults. The MASA estimates that a run of 72 adults is needed to achieved optimal egg deposition in the Pleasant River drainage. The potential for any river to produce Atlantic salmon is limited by the habitat available during the riverine stages of the salmon's life cycle (Dube and Jordan, 1982). A salmon river must have adequate spawning habitat, ready access to these areas, suitable nursery areas for juvenile salmon, and holding pools for the adults.

The MASA has performed detailed habitat mapping of the Pleasant River that documents the location of spawning and rearing habitat available for Atlantic salmon (Table 1). Habitat suitable for each lifestage of Atlantic salmon can be throughout the entire river basin. Key reaches were selected for specific lifestages for modeling in this study. A table summarizing all surveyed habitat in the Pleasant River appears in Appendix A. Tributaries to the Pleasant River also provide additional rearing and spawning habitat for salmon. Atlantic salmon spawning generally occurs in riffle areas with a stream bottom consisting of loose rubble 0.5-4.0 inches in diameter with varying quantities of sand and fine gravel (Dube and Jordan, 1982). Most redd construction in Maine occurs in water depths of less than 20 inches and at water velocities varying from 0.9-2.6 ft/sec. Young-of-year salmon (YOY) are most abundant over these areas, while parr show a preference for coarser bottom substrates in riffles or rapids. Juvenile salmon are frequently found in shallow water with or without boulders, if adequate cover is provided by aquatic vegetation, overhanging stream banks, overhanging branches, and/or smaller rocks.

2.3 Hydrology

The following is a general overview of basin hydrology, based on information available at this time.

Flow in the Pleasant River is unregulated (*i.e.*, naturally fluctuating). The dam at the outlet of Pleasant River Lake is not used to regulate flow. The dam, built in 1962, is owned by the MASA and leased to the Pleasant River Lake Association (personal communication, Ken Beland, MASA, January 14, 1999). The Association maintains the Pleasant River Lake dam and fishway.

Seasonal water withdrawals occur each year in the Pleasant River for irrigation of blueberry crops. Typically, irrigation occurs in June through mid August, with occasional frost protection irrigation required in May (W. Patrick, Cherryfield Foods, Inc., personal communication February 19, 1999). Permits for irrigation withdrawal from the Pleasant River have been issued by the Maine Land Use Regulatory Commission at the deadwater area approximately one mile downstream of Crebo Crossing, at “Farren Camp”, and on Bog Stream (a tributary). An additional withdrawal further downstream at “L Meadow”, is jurisdictional to Maine DEP.

The Maine Geological Survey (MGS) has gathered 11 years of gaged discharge data (period of record 1981-1991) for the Pleasant River, and has estimated monthly mean and median discharge values from these data for the Pleasant River at Epping (Table 2).

During 1998, water levels in the Pleasant River were monitored by the Pleasant River Watershed Council to estimate discharge at the discontinued USGS gage site at Saco Falls in Epping (www.state.me.us/asa, 1999). The goals of the program are to 1) compare current discharge to those conducive to growth and development of juvenile Atlantic salmon, 2) determine compliance with water withdrawal limits (voluntary or regulatory), and 3) determine the portion of discharge being withdrawn for irrigation purposes from the Pleasant River. The results of 1998 monitoring have not been published to date.

2.4 Surrounding Land Use

The Pleasant River watershed is sparsely populated. The headwater, Pleasant River Lake, is inhabited by camp owners and recreationists primarily during the summer. The lower reaches of the river include the small towns of Columbia, Columbia Falls, and Addison, with a combined population of about 2,100.

Silviculture and agriculture are the dominant land uses in the Pleasant River watershed (Maine Atlantic Salmon Task Force, March 1997). The forest resources are managed primarily for the harvesting and production of pulp for paper manufacturing and other wood products. Lands are also managed for wildlife and public recreation. On the Pleasant River watershed, relatively low acreage cuts are due in part to extensive spruce budworm salvage operations in the 1980s that produced a regenerating forest.

Wild blueberry culture is the primary form of agriculture in the Pleasant River watershed (Maine Atlantic Salmon Task Force, March 1997). Other types of agricultural activities and/or products in the watershed includes: dairy farming, hay, silage corn, horse farming, sheep farming, beef cattle farming, Christmas trees, market vegetables, cranberries, and landscape and horticultural plants.

Management agreement, conservation easement, or ownership strategies are currently being sought to better protect riparian zones of the Pleasant River of strategic importance to Atlantic salmon (Maine Atlantic Salmon Task Force, 1998). For example the Pleasant River Watershed Council (PRWC) recently worked with the Town of Columbia Falls to secure funds ($15,000) for the purpose of protecting riparian land next to critical Atlantic salmon habitat and creating public access to the Pleasant River.

3.0 METHODS

3.1 General Approach

YOY, parr (juvenile) and spawning Atlantic salmon habitat in the Pleasant River were evaluated using standard field procedures and habitat modeling techniques of the Instream Flow Incremental Methodology (IFIM), as developed by the National Ecology Research Center of the National Biological Survey (Bovee, 1982; Milhous et al. (1989). Adult habitat was assessed, but not modeled (Appendix E). The methodology involves modeling stream hydraulics of study reaches, and then quantifying habitat values of alternative stream flows using pre-determined habitat suitability index (HSI) criteria for selected evaluation species. HSI criteria are based on depth, velocity, substrate, and cover preferences of each lifestage of the evaluation species.

General modeling procedures involve collecting hydraulic data (*e.g*. bed profile, depth, current velocity, and water surface elevation at a series of known calibration flows) and habitat data (*i.e*. substrate and relevant cover characteristics) at a series of points (referred to as "verticals") along representative cross-sectional transects. Each pair of verticals along a transect defines the lateral boundaries of a "cell" that is assumed to be homogeneous with respect to depth, velocity, substrate, and cover. The length of stream represented by each transect is determined by field mapping. Hydraulic modeling predicts changes in depth and velocity in each cell as discharge varies. For each modeled discharge, the area of each cell is weighted relative to HSI criteria for each evaluation species life stage. Total units of habitat at each flow are calculated by summing weighted habitat area at all transect cells. Weighted Usable Area (WUA) is the standard unit of habitat calculated in standard IFIM computations: one unit of WUA is equal to one square foot of optimal habitat as defined by the habitat suitability criteria.

3.2 Scoping

The study was designed and implemented by members of the Flow Team of the LWRC with instream flow study expertise. This included biologists from MASA, USFWS, and MDIFW. The team provided input to the consultant (Kleinschmidt

Associates, KA) on technical issues, and determined study area boundaries, evaluation lifestages, specific HSI criteria, and modeling approach (Appendix A). The MASA and KA selected study site and transect locations in the field, based on MASA drainage-wide habitat survey using the Hankin-Reeves method (MASA memo dated July 15, 1998 – Appendix A) and MASA first-hand knowledge of salmon habitat in the Pleasant River.

The study area for the Pleasant River IFIM study (between Pleasant River Lake and the head of tide at Columbia Falls) was segmented into five independent reaches with boundaries located based on pronounced changes in topography, hydrology, and/or Atlantic salmon habitat (Table 1 and Figure 1). On August 24, 1998, the MASA and KA conducted a site visit to verify study reach boundaries and select representative study sites within each reach based on channel characteristics and habitat known to support key lifestages of Atlantic salmon. Reach types for YOY comprised low gradient riffles and runs. The reach types of interest for parr generally comprised shallow riffles, runs and glides with gravel, cobble, and boulder substrates (Appendix A). Reach types for spawning and egg incubation were deep riffles with gravel and cobble substrates. In addition, pool areas that serve as adult holding were documented, but not modeled. Five study reaches and fifteen transects were identified (Table 3).

Each study site was selected to represent a given type of habitat within the subject reach. The number and location of transects were placed within each study site as necessary to represent channel configuration, slope, hydraulics and/or substrate and cover. The total length of stream represented by each study site was determined by MASA from habitat mapping data for the Pleasant River (Table 3).

<u>Study Reach 1</u> extends from the headwaters of the Pleasant River downstream to Worcester Camp. Atlantic salmon habitat modeled in this reach was cobble and boulder riffles and runs that are typically 20 to 30 ft wide with good forest cover canopy. A single study site consisting of three transects was established in a riffle area.

<u>Study Reach 2</u> extends from Worcester Camp downstream approximately 2 miles too slightly downstream from Crebo Crossing, at an area referred to as Farren Deadwater. The stream gradient decreases, and the stream becomes slightly wider, open and

meandering. Atlantic salmon habitat in this reach consists of runs and moderate gradient riffles with gravel, cobble, and small boulder substrates. Riffles include coarse-substrate (primarily used for spawning) and mixed substrate riffle-run (used by YOY and parr). Two study sites (two transects at Hammond Camp and two transects at Crebo Crossing) were established.

Study Reach 3 extends from below Crebo Crossing downstream approximately 8 miles to Saco Falls. Most of this reach consists of meanders slowly flowing through the Great Heath, and habitat consists primarily of flowages/deadwaters with sandy and fine substrates of limited value to juvenile Atlantic salmon. However, small pockets of usable parr habitat exist in pea-gravel glide habitats, and adult holding areas are present in this reach. Taylor Brook, Ingersoll Brook, and Bog Stream are tributaries entering in this segment of the Pleasant River. Two study sites were located: one at L Meadow (a single transect to depict adult holding conditions) and at Farren Camp (two transects in glide habitat for parr). Because the L Meadow pool habitat is relatively deep and slow flowing, hydraulic microhabitat characteristics would not change appreciably at alternative flows and habitat modeling would not likely yield effective incremental decision making data. The study team therefore concluded that bed profile and depth data gathered at a range of field flows would be adequate to describe habitat conditions and make a general determination of suitability for adult holding (Appendix A).

Study Reach 4 extends from Saco Falls downstream to the confluence of the Western Little River. Salmon habitat is this reach includes riffles with small boulder, gravel, and cobble substrates that can be used by spawning, YOY and parr lifestages. There are no significant tributaries in this study reach. A single study site was established below the falls at Epping in a mixed substrate, split-channel riffle.

Study Reach 5, extends downstream from the confluence of the Pleasant and Western Little rivers, to the head of tide at Columbia Falls. Salmon habitat in this study reach generally consists of runs and riffles with gravel, cobble, and small boulder substrates. The river is substantially larger in this reach, and hydrology is influenced by inflow from the Western Little River. Two study sites were chosen. One was a coarse substrate, low gradient riffle area of importance for spawning, immediately downstream from the Western Little River (one transect). The second site was a mixed riffle/run complex located at Bailey's Campsite used for spawning, YOY and parr habitat (three transects).

3.3 Evaluation Lifestages

The study team recommended habitat availability evaluation for YOY, parr, and spawning lifestages of Atlantic salmon can be modeled using IFIM methods. The "spawning" or reproduction life stage refers to the eggs during the period from deposition by adults (October-November), through the incubation period of winter and early spring, when hatching occurs. Young-of-year (YOY) is a term used to refer to the two life stages during the first calendar year post hatching (i.e. YOY and 0+ parr). Parr, as used in this study, refers to year 1 parr (Jan. 1- June 30 the calendar year after hatching), 1+ parr (July 1 - Dec. 31 one year after hatching), *etc*.

Each species and lifestage-specific habitat use is rated using HSI criteria, in which parameters such as depth, velocity, and substrate are independently assigned rating values, based on research, literature, observations, and/or professional judgement (Bovee, 1982). Atlantic salmon HSI curves for this study were selected by the study team, and developed for use specifically on Maine streams (Appendix B). In addition, adult holding habitat was assessed by reviewing depth preference criteria at each of the three flows for which field data were obtained (Appendix E). High flow data were obtained so that hydraulic simulation could be achieved for spring (*i.e.* April median) flows in the event that there would be future interest in modeling smolt migration. However, no smolt HSI data were available for use in this report.

3.4 Field Methods

The field methods used in this study followed those recommended by Bovee (1982). Transect data were collected in accordance with data requirements for completing hydraulic modeling with the IFG4 model using a single velocity calibration data set. This entailed the collection of transect bed profiles, cover and substrate data, water surface elevations (WSEL's) at a series of calibration flows, mean-column-velocity calibration data at one flow, and stream discharge at each WSEL calibration flow.

Lateral boundaries of each study transect were defined by head- and tailpins established above the crest of each bank. Headpins were located along the right bank (looking downstream). Pins were field-blazed and semi-permanently fixed with either rebar or by using a large tree or other fixed object. At sites with multiple transects, longitudinal cell distance was also measured by established upstream and downstream boundaries which were located at observed shifts in cover, depth, hydraulics, or stream channel shape. These were also field-blazed to facilitate mapping. All transect location and mapping work was done at a time of low stream discharge to ease examination of stream channel characteristics.

Transect measurements proceeded as follows: fiberglass survey tape (accurate to 0.1 ft) or graduated, high-strength lines were secured between headpin and tailpin at each transect. Streambed elevation, mean-column-velocity, dominant substrate and edge of water were recorded at intervals (verticals) along the tape to the nearest 0.1 ft. Verticals were established at intervals wherever an observed change in any of the above four parameters occurred along each transect. This typically resulted in about 30 to 40 verticals per transect. Verticals were also arranged so that not more than 10% of the total transect discharge passed between any pair, in order to optimize the accuracy of the hydraulic model. At each vertical, depth was measured to the nearest 0.1-ft and substrate type was recorded. Bed and water surface elevations were surveyed to the nearest 0.01-ft elevation using a surveying level and standard surveying techniques. When necessary to establish backwatering effects of downstream obstructions, the elevation of stage-of-zero-flow was surveyed to the nearest 0.01 ft at the downstream hydraulic control of the study site.

Hydraulic data were collected at three calibration discharges (low, middle, and high), to facilitate modeling in a range from below August median flow up to April median flow according to study objectives.

Bed profile, substrate and cover data were collected at the low calibration flow. Water surface elevation (stage) was surveyed at each transect at all three flows. Velocity data were collected at all transects at the mid-flow; at transects containing complex hydraulics, an additional velocity data set was also collected at the low flow to enhance hydraulic calibration. Stream stage (water height) was recorded at temporary staff gages installed in the vicinity of each transect or study site at the beginning and end of velocity measurements and before and after water surface elevation measurements at each transect. This verified that no significant changes in stage or discharge occurred during hydraulic measurements along each transect. At the velocity calibration flow, mean-column-velocity and depth were measured at all wetted verticals.

Depth was measured to the nearest 0.1-ft, and velocity was measured to the nearest 0.1-ft/s using a calibrated Marsh-McBirney Model 2000 Flowmate electronic current meter attached to a top-setting wading rod. In water less than 2.5-ft deep, mean-column-velocity was measured at 0.6 of the depth. In very turbulent areas less than 2.5 ft deep and in water greater than 2.5-ft deep, mean-column-velocity was taken as the average of the velocities measured at 0.2 and 0.8 of the depth.

Stream discharge at each study reach was determined by computations from collected depth, width and velocity data in an open channel location in the study site vicinity, using standard stream gaging techniques. In some cases it was possible to employ a habitat transect.

Flow on the Pleasant River is unregulated, and therefore fieldwork was scheduled to occur whenever precipitation created river discharges in a target range for model input. Because flow conditions could be ephemeral, the USGS gage for the Narraguagus at Cherryfield (Gage No. 01022500) was monitored daily to indicate appropriate study flow conditions for the Pleasant River. Pleasant River flow conditions could be predicted adequately using the Narraguagus gage because both are adjacent watersheds that are unregulated, and receive similar weather patterns. In addition, the Pleasant River Watershed Association supplied updated flow monitoring information from Saco Falls.

3.5 Hydraulic Modeling

In general, the IFG4, MANSQ and WSP hydraulic models are used in calibrating the hydraulic model component of PHABSIM (Milhous, *et al*., 1989). The choice of specific model(s) was based on the hydraulic characteristics of each transect. MANSQ or WSP and a log-log fit were compared to select the model which best established the stage-discharge relationship across the flow range of interest, and IFG4 was run to simulate velocity in each cell along each transect at the flow increments of interest.

The first step of modeling involved establishing the stage-discharge relationship for each transect. Next, calibration of the model for velocities consisted of calculating the Mannings equation roughness coefficient, given field measured velocities and stream slope values to allow the predicted velocity values to correlate in the model as closely as possible to each corresponding velocity recorded during calibration flows.

3.6 Habitat Modeling

Habitat area was computed independently for each study site using the HABTAE option in PHABSIM. HABTAE is the standard program applied to rate habitat availability at each specified flow increment by combining hydraulic output with habitat suitability criteria. Habitat and wetted area output for each site is expressed in standardized units of area (square feet) available per 1,000 ft. of similar stream reach for each lifestage and flow increment. One unit of Weighted Usable Area (WUA) corresponds to 1 square foot of optimal habitat. This habitat area estimate was then expanded for the actual area represented by the transects within the reach according to the MASA reach habitat mapping data.

HABTAE calculates WUA for each projected flow at each transect, based on the parameters (depth, velocity and wetted substrate) forecast for each wetted cell by the hydraulic model as they relate to the HSI criteria established for the species and lifestage of interest, and the dimensions of the cell. For each wetted cell, the program rates each criterion on a scale of 0.0 to 1.0, multiplies these values together with the established area of the cell, and sums all the resulting areas.

The discharge (cfs) simulation steps varied among reaches, but were based on the relative drainage area and estimated discharges (cfsm) for each reach. Drainage area estimates for each study reach were developed by obtaining basin mapping data (MGS web site) and planimetering sub-basin boundaries (Appendix A). Approximately 0.1 cfsm increments in a range were used from 0.1 to 1 cfsm**,** and 0.5 cfsm increments between 1.0 and 4.5 cfsm. This gave relatively high resolution in the lower end of the flow range. This approach allows the model to predict habitat for discharges roughly spanning the range from well below August or September median flow up to the historic April median flow (as recorded at the Epping gage located at the head of Reach 4).

The WUA output for each habitat was then expanded to the reach, based on the length of corresponding habitat within the reach provided by MASA. These stream length for given habitats were developed from GPS coordinates and detailed habitat descriptions previously developed as part of the overall MASA Atlantic salmon management program for the Pleasant River.

4.0 RESULTS

Calibration flow data were collected on August 24-26, October 10-13, and October 16, 1998. Discharge ranges, at Epping on those dates were 30-47 cfs, 108-145 cfs and 183 cfs, respectively (Table 4). Stream gage data taken instantaneously at the time of microhabitat measurements at individual transects are presented in Table 5. Measured discharge progressively increased from upstream to downstream, reflecting increases in tributary and groundwater inflow throughout the drainage. During low-flow conditions, instantaneous measured stream discharge ranged from approximately 1.6 cfs in the upper study reach near Worcester Camp to approximately 47 cfs in the lowermost reach at Bailey's Campsite above Columbia Falls. During mid-flow field conditions, flow was measured as 23.1 cfs near Worcester Camp and 149.9 cfs at Bailey's Campsite. During high flow, flow at these two reference points was 48.8 and 402 cfs, respectively.

Because each study reach is considered an independent study segment, the results are presented separately for each reach, beginning upstream. Bed and water surface profiles for each transect are presented in Appendix C, and photos of study sites are in Appendix D.

Wetted Area and Weighted Usable Area

4.1 Reach No. 1 – Pleasant River Lake to Worcester Camp

Atlantic salmon habitat modeled in this stream reach is characterized by cobble-boulder dominated riffle/pocket pool habitat, and is utilized by the YOY and parr. A total of 2,865 ft of this type of habitat occurs in this reach (Table 3). A study site comprising three transects was used to represent this habitat. Bed profiles in this reach were irregularly shaped, due primarily to the presence of large, coarse substrates such as boulder (Appendix C). Discharge was field measured across a range of 1.6 to 48.8 cfs, in this reach. The estimated drainage area of this reach, as measured at Worcester Camp, is approximately 20 square miles, with approximately 15 square miles occurring upstream from Pleasant River Lake.

4.1.1 Hydraulic data

Flows were modeled in a range from 2 to 90 cfs. Wetted area increased rapidly from 2 to 6 cfs, reflecting inundation of the stream channel from bank toe to toe (Table 6, Figure 2). Further increases in wetted area were more gradual, as flow in the channel reacted primarily by deepening and thus instream boulder and cobbles became inundated, adding slightly to wetted area.

4.1.2 Habitat data

Weighted Usable Area (WUA) per 1,000 foot of stream length for YOY rises sharply between 2 and 6 cfs, where 96% of the peak potential habitat occurs (Table 6). The YOY WUA reaches a plateau at 10-12 cfs, and then gradually declines across the remainder of the flow range. This decline reflects depth and velocity increases occurring in mid channel that exceeds the optimal criteria for the lifestage. WUA for the parr lifestage increases sharply between 2 and 12 cfs, where an inflection point occurs, and 94% of the peak potential habitat area is created. WUA continues to gradually increase between 12 and 30 cfs, where the absolute peak WUA occurs.

4.2 Reach No. 2 – Worcester Camp to Crebo Bridge

Atlantic salmon habitat modeled in this stream reach includes low-gradient, coarse substrate riffles suitable for spawning, and mixed-substrate moderate gradient run habitat suitable for YOY and parr. A total of 3,725 ft of spawning riffle habitat and 7,914 ft of run is reported to occur in this reach (Table 3). A study site was located in each habitat type, each had two transects. The bed profile of the spawning riffle was defined by gravel deposits, and fell into two types: one was a symmetrical, trough shaped channel, with a thin thalweg, and the second was asymmetrical, with mounded, shoaled gravel deposits (Appendix C). Discharge was field measured across a range of approximately 3.8 to 70.1 cfs, in this reach, as measured near Crebo Bridge. The estimated drainage area contributing discharge to this reach, as measured at Crebo Bridge, is approximately 26 square miles.

4.2.1 Hydraulic Data

Flows were modeled in a range from 2 to 104 cfs in the spawning riffle. Wetted area increased rapidly up to 14 cfs, reflecting filling of the stream channel from bank to bank. Wetted area increased more gradually at a relatively steady rate across the remaining flow range, reflecting inundation of the stream channel from bank toe to toe (Table 7, Figure 3). Some minor inflections and peaks occurring at 16, 44 and 68 cfs reflect inundation of portions of gravel bars.

A flow range of 2.5 to 130 cfs was modeled in the run habitat. Wetted area increased rapidly to 10-15 cfs, when the channel was filled. At higher flows increases in wetted area were more gradual, as the channel reacted primarily by deepening (Table 8, Figure 4).

4.2.2 Habitat Data

Weighted Usable Area (WUA) per 1,000 foot of stream length for spawning increaed sharply between 2 and 14 cfs, where 63% of the peak potential habitat occurs (Table 7). No significant increases in spawning area occur, until additional riffle is sufficiently inundated, between 32 and 56 cfs, where the absolute peak occurs. At a flow of 2.5 cfs, 82% of the peak potential YOY WUA exists, as a significant amount of the channel is wetted and suitably deep (Table 8). WUA gradually reaches a peak at 20 cfs, and slowly declines across the remainder of the flow range, reflecting depth and velocity increases occurring in mid channel that exceed the optimal criteria for the lifestage. Approximately 70% of the peak potential WUA for the parr lifestage exists at 2.5 cfs, but increases to approximately 90% at 7.5 cfs, and reaches an absolute peak at 25 cfs. A plateau is reached between approximately 15 and 40 cfs, where changes in parr WUA do not appear to be pronounced. Parr WUA declines steadily at discharges greater than 40 cfs.

4.3 Reach No. 3 – Crebo Bridge to Saco Falls

Atlantic salmon habitat modeled in this reach was low-gradient run with pea gravel substrate and clumps of rooted aquatic vegetation. This habitat type is sometimes referred to as a "glide" (Gregg Horton, MASA personal communication). This habitat is most suitable for parr. A total of 6,190 ft of glide habitat is reported to occur in this reach (Table 3) primarily in the section Crebo to Farren Camps. A study site, with two trasects, was located in a glide near Farren Camp. The bed profile of the glide habitat consists of a steep-sided U- shaped channel, with a slight thalweg (Appendix C). A review of adult holding characteristics is presented in Appendix E. Discharge was field measured across a range of approximately 13.9 to 102.4 cfs, in this reach, as measured at Farren Camp. The estimated drainage area contributing discharge to this reach as measured at Farren Camp is 37 square miles, and at the downstream limit of the reach (near Saco Falls) is approximately 61 square miles.

4.3.1 Hydraulic data

Flows were modeled from 4 to 180 cfs. Wetted area increased rapidly up to 16 cfs, reflecting filling of most of the stream channel from bank to bank, followed by very little further increase to 60 cfs. A second, smaller increase in wetted area occurred between 60 and 80 cfs, as a shelf area along one bank became submerged (Table 9, Figure 4). No significant additional wetted area occurred at higher flows, as the channel reacted by deepening in response to increased flow.

4.3.2 Habitat data

Weighted Usable Area (WUA) per 1,000 foot of stream length for parr rises most sharply between 4 cfs, where 91% of the peak potentially available exists, and 8 cfs, where 99% of the peak potential habitat occurs (Table 9). The peak potential habitat occurs at 12 cfs. Parr WUA declines across the remainder of the flow range, primarily reflecting velocity increases occurring in mid channel exceeding the optimal range for the lifestage.

4.4 Reach No. 4 – Saco Falls to confluence with Western Little River

Atlantic salmon habitat modeled in this reach was mixed-substrate riffle suitable for spawning, YOY and parr. A total of 3,967 ft of this type of riffle habitat is reported to occur in this reach (Table 3). A study site was located below Saco Falls, comprising two sub-transects to account for a minor- and major split channel around an island. The bed profile of both channels of the riffle formed an irregular V-shape, with a poorly pronounced thalweg. Bed profile irregularities were primarily a result of large cobble and boulder substrates (Appendix C). Discharge was field measured across a range of approximately 32.2 to 187.1 cfs, in this reach, as measured at Saco Falls. The estimated drainage area contributing flow to this reach is approximately 61 square miles.

4.4.1 Hydraulic data

Net flow through the study site was modeled in a range from 6 to 270 cfs, with discharge routed through each channel based on field measurements at each calibration flow. Thus the main channel was modeled from 6 to 211 cfs, and the minor channel was modeled from 0 to 69 cfs. Wetted area and WUA results from each channel were summed for this analysis (Table 10). Wetted area increased rapidly up to 18 cfs, reflecting filling of the stream channel from bank to bank.

Wetted area increased more gradually, but slightly erratically between 18 and 60 cfs, reflecting intermittent inundation of various boulder clusters and shoal areas on the headpin side of the main channel transect as flows increase (Table 10, Figure 5, Appendix C). Only slight increases in wetted area occurred above 90 cfs.

4.4.2 Habitat data

Weighted Usable Area (WUA) per 1,000 foot of stream length for spawning remained relatively low throughout the entire flow range, with no pronounced inflection points or peaks (Table 10). Absolute peak WUA for this lifestage occurred at 120 cfs.

There was somewhat more YOYand parr habitat available than spawning at any given flow. At a flow of 6 cfs, 57% of the peak potential YOY WUA exists, as a significant amount of the channel is wetted and suitably deep. YOY WUA gradually reaches an absolute peak at 30 cfs, but the differences in the amount of habitat area are not pronounced between 24 and 60 cfs. This occurs as flow increases across this range, and newly inundated areas create habitat at approximately the same rate that other channel areas lose habitat value by becoming deeper or swifter than optimal for the lifestage. YOY WUA declines slowly at higher flows, reflecting gradual depth and velocity increases occurring in mid channel that exceed the optimal criteria for the lifestage.

Approximately 42% of the peak potential WUA for the parr lifestage exists at 6 cfs, but increases sharply to approximately 88% at 30 cfs (the flow at which YOY WUA peaks), and reaches an absolute peak at 90 cfs. A plateau is reached between approximately 36 and 150 cfs, where changes in parr WUA do not appear to be pronounced for similar reasons as noted for YOY. Absolute peak potential parr WUA occurs at 90 cfs.

4.5 Reach No. 5 – Western Little River to Columbia Falls

Atlantic salmon habitat modeled in this reach included low-gradient, coarse substrate riffle suitable for spawning, and mixed-substrate moderate gradient run habitat suit able for spawning, YOY and parr. A total of 2,616 ft of spawning riffle habitat and 1,082 ft of mixed substrate riffle habitat is reported to occur in this reach (Table 3). A study site was located in each habitat type. One transect was located in a large spawning riffle just downstream from the confluence with the Western Little River. The bed profile of the spawning riffle was defined by ridged gravel deposits, and featured a trough shaped channel, with a narrow thalweg (Appendix C). The mixed substrate riffle was represented by three transects to account for variations in channel geometry and substrate. In general, this channel was characterized by a U-shaped channel, with a mix of gravel and cobble, and either isolated individual boulders or occasional boulder/cobble clumps (Appendix C). Discharge was field measured across a range of approximately 47 to 402 cfs, in this reach, as measured at Bailey's Campsite. The estimated drainage area contributing flow to this reach is approximately 94 square miles.

4.5.1 Hydraulic data

Flows were modeled in a range from 8 to 360 cfs in the spawning riffle. Wetted area increased rapidly up to 24 cfs, reflecting filling of the stream channel from bank to bank. Wetted area increased only slightly across the remaining flow range (Table 11, Figure 6).

A flow range of 10 to 450 cfs was modeled in the mixed substrate riffle habitat. Wetted area increased rapidly to 40 cfs, when the channel was filled from bank to bank. At higher flows increases in wetted area were more gradual, boulders and shoals were submerged as flow increased (Table 12, Figure 7).

4.5.2 Habitat data

Weighted Usable Area (WUA) per 1,000 foot of stream length in the spawning riffle rises sharply between 8 and 120 cfs, where 87% of the peak potential habitat occurs (Table 11). Absolute peak spawning WUA occurs at 160 cfs.

Spawning habitat was also evaluated at the mixed riffle study site. Spawning WUA increased rapidly between 10 and 80 cfs, where 93% of the peak potential WUA is created (Table 12). The absolute peak WUA occurs at 100 cfs, although there is a plateau between 90 and 100 cfs, where changes in WUA are not pronounced. At a flow of 10 cfs, 82% of the peak potential YOY WUA exists, as a significant amount of the channel is wetted and suitably deep. WUA reaches a peak at 30 cfs, and subsequently declines across the remainder of the flow range, reflecting depth and velocity increases occurring in mid channel at higher flows that exceed the optimal criteria for the lifestage. Parr WUA increases sharply from 10 to 40 cfs where 97% of the WUA occurs. Flows in a range between 50 and 90 cfs all produce similar and relatively optimal amounts of WUA. As flow increases, shallow and edge cells become increasing suitable for parr, while mid-channel cells experience an increase in deeper and swifter hydraulics that exceed the optimal criteria for the life stage. At flows greater than 90 cfs, parr WUA declines, as the riffle habitat becomes increasingly deeper and swifter.

4.6 Total Habitat Area

The total estimated habitat area, by reach, available for each modeled habitat type across the flow range for applicable lifestages varied among the reaches (Table 13). For example, the greatest amount of spawning area (132,252 sq. ft) in the basin is estimated to exist in the large spawning riffle of reach number 5 at a flow of 160 cfs. That same flow produces approximately 19,000 sq. ft of spawning area in the mixed riffle habitat located elsewhere in the same reach. The greatest amount of basinwide YOY habitat (approximately 119,000 sq. ft) occurs in reach number 2 run habitat at a flow range of approximately 15-20 cfs. The next greatest YOY WUA (48,644 sq. ft) exists in reach 4 at a flow range of 30 cfs. Reach number 2 run habitat provided the greatest amount of potential parr habitat (139,543 sq. ft) at 25 cfs. The next greatest total potential parr area was created in reach number 4 at a flow of 90 cfs. The reader should be cautioned, however, to not take these areal estimates too literally. They portray a general index of trends in habitat availability across flows and reaches based on habitat quality, and are not intended to be a precise count of habitat units in the Pleasant River.

5.0 DISCUSSION

According to the Conservation Plan, the objective of the water use management plan is to:

"*a)* *account for Atlantic salmon water needs on the Pleasant, Narraguagus and Machias Rivers"*, and

b) *assess stream flow at significant habitat sites during dry periods...and determine in-stream flow based on Atlantic salmon needs for rivers with irrigation or potential for irrigation*"

The purpose of this discussion is to indicate to those developing a water management plan how these data may help determine instream flows that are protective of Atlantic salmon habitat. The relationships between habitat and flow detailed in this report ultimately should be put in the context of the natural, temporal, and spatial pattern of flow of each reach of the Pleasant River.

5.1 Time Series For Each Life Stage

According to the MASA (1998), adult Atlantic salmon begin to enter the Pleasant River in the spring, and episodically ascend the river to holding areas throughout the summer in response to increases in flow and changes in water temperature. Spawning occurs in late October to early November, with exact dates triggered by a combination of day length, temperature, and flow. Eggs are buried in coarse, clean gravel/cobble beds, called "redds" constructed by the female salmon. After spawning, adult fish may leave the river in the fall or remain in the river throughout the winter to leave as "kelts" the following spring.

Egg incubation requires constant flow through the redds to aerate and clean interstitial waters, and prevent anchor ice from forming. In late April, yolk-sac fry hatch and remain in the gravel interstices. Fry emerge from the substrate and enter shallow, low-velocity nursery areas. These fish are considered young-of-year (YOY) and remain in the nursery habitat for the remainder of the year. During winter months and also during summer daylight hours, juvenile salmon may burrow in gravel to avoid stress and predation. During the second year of life, the juveniles (parr) continue to occupy nursery habitat for a full year, and emigrate to sea in April-June (of either the second or third anniversary of hatching). Based on this life cycle, the Flow Team defined specific months as critical for each respective early life stage of Atlantic salmon, based on the timing of their occurrence in the Pleasant River (Table 14).

During October through April, habitat needs for spawning and egg incubation should define flow recommendations, whereas during April through September, YOY and parr habitat requirements should be considered when recommending flows. Other aspects of salmon biology, and general ecology were beyond the scope of this analysis. For example, flow and habitat needs for Atlantic salmon smolts during their downstream migration. Other instream flow issues of general ecological concern - *e.g.* fish passage, brook trout population maintenance, brook trout angling and water quality as it relates to indigenous aquatic life were not quantitatively analyzed.

5.2 Habitat Available Under Existing Conditions

Effective available habitat assumes that a naturally occurring low flow cycle may constrain a population. However, it does not assume that perpetuating such a flow as a maximum flow through a policy recommendation necessarily optimizes fish populations. It is defined by the flow period that produces the lowest habitat area during the period of the year the life stage exists in the stream (Bovee 1982). In an Effective Habitat Time Series analysis, an optimal habitat flow recommendation is typically derived from monthly hydrograph data. IFIM studies of this type generally use monthly hydrologic units, assuming that the quantity of habitat resulting from a particular flow level over that length of time would affect populations due to space, competition, predation, etc. (Bovee, 1982). Other time increments may be used if there is a scientific basis to do so, and sufficient time series flow information to support the analyses.

If multiple life stages of a given species are considered within the study area, the approach begins by defining maximum effective habitat as the smallest amount of habitat available over time, based on natural inflow, for what is considered the limiting life stage. This effective habitat attainment percentage would then carry over to flow recommendations for other life stages after applying any appropriate habitat ratios, if such data area available (Bovee 1982). In the absence of such data, a 1:1 habitat ratio among life stages is assumed. Habitat ratios reflect the relative spatial needs of various life stages and rely upon detailed knowledge of population dynamics as well as physical and environmental factors controlling the Atlantic salmon population. The Flow Team concluded, for purposes of this study, that the information does not presently exist to designate any single life stage as necessarily limiting, nor are data available to adjust habitat ratios beyond the conventional 1:1 relationship.

Monthly time steps are commonly used in flow analyses, because available hydrologic data are typically reported in that manner. Monthly units can alternatively be collapsed into biologically-defined seasons if longer temporal habitat use is important. However, other time increments can be used if hydrology, biology, or project operations reasons require them. The monthly median flow is the conventionally used statistic for decision-making, as it represents a flow that will be equaled or exceeded 50% of the time during any given month. As a measure of central tendency, median flow statistics are less sensitive to infrequent high outliers than are mean flow statistics. At least that much flow is therefore expected to be available on half the days of the month, and therefore the median is considered a reasonable indicator of "typical" flow for the month in question on a "normal" water period (*i.e.* not a drought or wet period).

Parr and YOY would typically experience the lowest monthly median flow during September, based on the hydrologic record for the Pleasant River (MGS 1998). It should be noted that as part of the Conservation Plan, a more refined hydrologic analysis is underway for this stream that may serve to re-define the frequency and magnitude of flows during low-flow periods. For purposes of this discussion, however, we rely on the available MGS (1998) data. Thus, the amount of flow available in each of the five stream reaches during the naturally-occurring low flow month (currently defined as September) would serve to define effective habitat availability for these lifestages. Spawning may occur as early as late October, when discharges are reportedly lowest for the two-month window for nest building and egg deposition. Subsequent months of incubation typically experience higher median discharges. Since the amount of habitat produced during October will limit where adult salmon will locate redds, the subsequent months of stationary egg incubation should be protected by the higher overall flows occurring later throughout the late fall, winter, and early spring. Conversely, if fish spawn during a period of higher fall flow (e.g. November), some redds may be constructed in areas of somewhat higher bed elevation, and require sufficient flow to remain submerged throughout the incubation period.

During the low flow summer period, two life stages (YOY and parr) overlap in time and space. As noted above, both lifestages are equally prioritized in recommending flow, and experience different optimal habitat flows, with fry habitat peaking at lower flows than parr. Thus, no one flow in a particular reach will concurrently optimize habitat for both lifestages.

The Flow Team identified both optimal and minimally acceptable habitat standards from the study data. Optimal habitat conditions were defined as those that produce the maximum amount of habitat area in the existing stream reach. The closer that stream flow conditions can come to maintaining optimal habitat, the more likely the river will successfully provide nursery habitat for Atlantic salmon. A flow producing "optimal" habitat is functionally defined as the flow (or flows) capable of concurrently producing the highest amount of potentially available habitat area for all life stages overlapping in time irrespective of flow availability.

The flow producing "minimal" habitat was defined as that flow occurring at the WUA inflection point (i.e. the flow at which the rate of habitat loss, as flow declines, begins to increase at a relatively large rate). In cases where two life stages overlap and have WUA inflection points at different flows, the higher flow of the two life stage's inflection points was selected. Flows lower than this inflection point are assumed to provide an amount of nursery habitat that is potentially limiting the ability of the stream reach to sufficiently support Atlantic salmon production. Based on the present understanding of the Pleasant River hydrology, it was also assumed that monthly median flows in all reaches meet or exceed the "minimal" habitat level.

The following summary identifies the optimal habitat-based discharges (cfs) identified in each reach by the Flow Team for each month, based only on the discharge and WUA relationship (i.e. hydrologic budget not yet considered):

reach	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR
1	16	16	16	16	16	60	60	60	60	60	60	60
2	21	21	21	21	21	56	56	56	56	56	56	56
3	12	12	12	12	12	12	12	12	12	12	12	12
4	60	60	60	60	60	120	120	120	120	120	120	120
5	40	40	40	40	40	160	160	160	160	160	160	160

The following table identifies the minimal habitat-based discharges (cfs) identified by the Flow Team for each reach, based on an inflection point analysis of the WUA data1:

reach	YOY	parr	spawn
1	6	10	30
2	-	-	44
3	-	8	-
4	30	30	90
5	20	30	120

The following table indicates the range of habitat-based flows, from minimal to optimal habitat conservation, in each reach, identified by the Flow Team, based on the WUA data:

reach	May-Sept	Oct-April
1	10-16	30-60
2	8-21	44-56
3	8-12	12
4	30-60	90-120
5	30-40	120-160

This study quantitatively estimated relative habitat availability across a discharge range from below the estimated lowest monthly median flow, up to at least the April median flow for each selected life stage of Atlantic salmon in stream reaches spanning the entire main stem of the Pleasant River. Although the above analysis indicates how a range of flows potentially affects habitat availability, it does not put these data in perspective of natural flow and establish the baseline of effectively available habitat for each life stage in each stream reach under existing conditions. To accomplish this, the amount of habitat defined by reach specific hydrologic estimates (being developed independently by the U.S. Army Corps of Engineers) should be reviewed. It is recommended that both "normal" and "drought" scenarios be defined, and to the extent possible, the frequency and duration of each scenario be estimated based on the best available hydrologic data.

In reviewing available hydrologic data, planners should consider the following:

1. A reasonable estimate of the how the hydrograph changes in reaches removed from the Epping reach (Reach 4) is necessary in order to predict habitat availability in those reaches.

2. The accuracy of the 11-year period of record at Epping in typifying the range of flows encountered should be addressed. If that period of record is insufficient, then alternatives should be developed. These may include:

- record extension (*i.e.* apply the longer time series that exists for the neighboring Narraguagus River basin (if possible) as a proxy)
- interim flow recommendation - base a flow recommendation on best available hydrology and reasonable assumptions, and collect additional data to enhance the period of record and/or gain reach-specific flow information.

3. As thresholds of acceptable flows are being set, a risk analysis should be performed (keeping the above in mind) to determine the likelihood that certain habitat threshold levels are met or exceeded given the flow record. This can be done by viewing reach-specific discharge data as a duration curve.

In reviewing the habitat data for each reach, in light of the available hydrologic information, planners should remember:

1. Often there is an inflection point that indicates the discharge below which a significant percentage of the potentially available habitat in a reach is lost.
2. There is rarely a flow that produces a distinct "peak" of habitat area; rather there often exists a range of flows that all produce relatively similar amounts of habitat.
3. The discharge(s) required to produce optimal potential habitat in a particular reach may exceed the monthly median flow defining effectively available habitat.
4. It is also advisable to verify that a biologically-based flow recommendation does not introduce a secondary, unmodeled problem, such as restricted zone-of-passage through riffles, elevated stream temperature, or limiting habitat changes for other ecologically or economically important aquatic resources.

5.3 Habitat Available Under Alternative Conditions

Minimum flows that are both protective of habitat for applicable life stages of Atlantic salmon, and address water withdrawal concerns should be identified independently for each reach. Proposed withdrawal locations, and quantities should be reach-specifically identified, and the duration of the withdrawals should be established in monthly units. Withdrawals should then be iteratively reviewed by determining the amount of effective habitat availability achieved under each resulting flow regime until scenarios can be developed that sufficiently address objectives.

6.0 LITERATURE CITED

Baum, E.T. 1997. Maine Atlantic Salmon Management Plan with Recommendations Pertaining to Staffing and Budget Matters. Maine Atlantic Salmon Authority. Bangor, ME. 57pp.

Baum, E.T., M. Evers, G. Horton and R. Spencer. 1998. 1997 Endangered Species Project Report. Maine Atlantic Salmon Authority, Bangor, ME. 78 pp.

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Office of Biol. Serv., USFWS, U.S. Dept. Of Interior, Wash., DC. FWS/OBS-82-26. 248 pp.

Dube, N.R., and R.M. Jordan. 1982. The Pleasant River. An Atlantic salmon river Management Report. Prepared for the Atlantic Sea Run Salmon Commission *in* A River Management Report by the Atlantic Sea Run Salmon Commission. Narraguagus and Pleasant. Bangor, ME. 69 pp.

Horton, G., M. Evers, R. Spencer and E. Baum. 1998. 1997 Endangered Species Project Report, Contract No. 14-48-0005-93-9035, Annual Report Number 4, May 1, 1997-April 30, 1998. Maine Atlantic Salmon Authority, Bangor, Maine. 78 pp.

Maine Atlantic Salmon Authority. 1998. Pleasant River instream flow incremental methodology. Request for proposals. Maine State Planning Office, Augusta, ME.

Maine Atlantic Salmon Authority. January 1, 1999. 1998 Pleasant River Discharge Monitoring Project. Maine Atlantic Salmon Authority, Bangor, ME. www.state.me.us/asa/pleasd~1.html

Maine Atlantic Salmon Task Force. 1997. Atlantic Salmon Conservation Plan for Seven Maine Rivers.

Maine Atlantic Salmon Task Force. 1998. Land & Water Resources Council 1998 Annual Progress Report.

Maine Department of Conservation (MDOC). 1982. Maine Rivers Study. Vol. 1-3. Prepared for the U.S. Dept. of Interior, National Parks Serv. Mid-Atla. Reg. Office. Augusta, ME. 249 pp.

Maine Geological Survey, Natural Resources Information and Mapping Center. Department of Conservation. 1998. Analysis of Median Flow in Selected U.S. Geological Survey Gaging Stations in Washington County, Maine. Prepared for the Atlantic Salmon Conservation Plan Technical Committee. 9 pp.

Milhouse, R.T., M.A. Updike, and D.M. Schneider. 1989. Physical habitat simulation system reference manual - Version II. U.S. Dept. Of Interior, Fish and Wildl. Serv. Wash., DC. Biol. Rept. 89(16). v.p.

TABLES

Table 1. Summary of Pleasant River Atlantic salmon habitat modeled, by reach and lifestage.

Stream reach	**Description**	**Spawning** ***(riffles)***	**YOY** ***(riffles and runs)***	**Juvenile** ***(riffles, glides and runs)***	**Adult** ***(pools)***
1	Pleasant River Lake to Worcester Camp Riffles		X	X	
2	Worcester Camp Riffles to Farren backwater	X	X	X	
3	Farren backwater to Saco Falls			X	X
4	Saco Falls to confluence with Western Little River	X	X	X	
5	Western Little River to Columbia Falls old dam	X	X	X	X

NOTE: "X" indicates life stage and habitat modeled in reach.

Table 2. Mean and median monthly flows in the Pleasant River at Epping.
Period of record: July 29, 1980 to September 30, 1991. Data from MGS, 1998.

Month	**Mean Discharge (cfs)**	**Median Discharge (cfs)**
January	104.9	89.0
February	160.7	116.5
March	197.9	148.0
April	306.3	270.5
May	189.8	155.5
June	118.2	87.0
July	69.5	53.5
August	67.7	50.0
Sept	64.1	44.0
October	86.0	67.0
November	158.0	139.0
December	174.0	120.0

Table 3. Pleasant River Atlantic salmon IFIM study. Study site and transect configuration.

Study Reach Number	Study Site Location	Number of transects	Habitat Type	Lifestage	Represented Stream Length (ft)
1	Worcester Camp	3	Riffle	YOY, parr	2,865
2	Hammond Camp	2	Gravel riffle	Spawning	3,725
2	Crebo Crossing	2	Moderate-gradient run	YOY, parr	7,914
3	Farren Camp	2	Glide	parr	6,190
3	“L” Meadow	1	Low-gradient run/pool	Adult holding area	423
4	Saco Falls	1	Moderate-gradient riffle	YOY/parr/spawning	3,967
5	Arties Bridge	1	Gravel riffle	Spawning	2,616
5	Baileys	3	Boulder riffle	YOY/parr/spawning	1,082

Table 4. Pleasant River IFIM study. Summary of field survey dates and prevailing river flows (as measured at Epping, Maine).

				Approximate prevailing flows (CFS)		
				low flow	*mid flow*	*high flow*
			discharge @ Epping*	30-47	108-145	183
River	**study site**	**life stages modeled/habitat type**	**reach no.**	**Date**	**Date**	**Date**
Pleasant	Baileys Campsite	*spawning/YOY/juvenile run/riffle*	5	08/24/98	10/14/98	10/16/98
	Arties Bridge	*spawning gravel riffle*	5	08/26/98	10/14/98	10/16/98
	Saco Falls	*spawning/YOY/parr riffle*	4	08/26/98	10/14/98	10/16/98
	L Meadow	*parr (juvenile) run - low gradient*	3	08/26/98	10/14/98	10/16/98
	Farrin Camp	*parr run - low gradient pea gravel/veg.*	3	08/25/98	10/14/98	10/16/98
	Crebo Crossing	*juvenile/YOY run - medium gradient*	2	08/25/98	10/14/98	10/16/98
	Hammond Camp	*spawning gravel riffle*	2	08/25/98	10/13/98	10/16/98
	Worcester Camp	*parr run/riffle*	1	08/25/98	10/13/98	10/16/98

* Reported by the Pleasant River Watershed Association and/or Downeast Salmon Federation

Table 5. Pleasant River IFIM study. Summary of stream gage data gathered at individual study sites.

Low Flow

Study site	transects	Flow (cfs)	Date
Baileys Campsite	P-1 through P-3	46.95	08/24/98
Arties Bridge	P-4	38.32	08/26/98
Saco Falls	Saco Falls Dam	32.18	08/26/98
Saco Falls	P-5a (sm. channel)	2.08	08/26/98
L Meadow	P-6	20.06	08/26/98
Farrin Camp	P-7	13.91	08/25/98
Farrin Camp	P-7a	11.93	08/27/98
Crebo Crossing	P-8 & P-9	3.79	08/25/98
Hammond Camp	P-10 & P-11	2.46	08/25/98
Worcester Camp	P-12 through P-14	1.63	08/25/98

Mid Flow

Study site	transects	Flow (cfs)	Date
Baileys Campsite	P-1 through P-3	149.90	10/14/98
Arties Bridge	P-4	135.90	10/14/98
Saco Falls	Saco Falls Dam	132.00	10/14/98
Saco Falls	P-5a (sm. channel)	13.60	10/14/98
L Meadow	P-6		
Farrin Camp	P-7 & 7a	37.40	10/14/98
Crebo Crossing	P-8 & P-9	24.90	10/14/98
Hammond Camp	P-10 & P-11	29.00	10/13/98
Worcester Camp	P-12 through P-14	23.10	10/13/98

High Flow

Study site	transects	Flow (cfs)	Date
Baileys Campsite	P-1 through P-3	402.00	10/16/98
Arties Bridge	P-4	322.80	10/16/98
Saco Falls	Saco Falls Dam	187.10	10/16/98
Saco Falls	P-5a (sm. channel)	32.30	10/16/98
L Meadow	P-6		
Farrin Camp	P-7 & 7a	102.40	10/16/98
Crebo Crossing	P-8 & P-9	70.10	10/16/98
Hammond Camp	P-10 & P-11	64.90	10/16/98
Worcester Camp	P-12 through P-14	48.80	10/16/98

Table 6. Pleasant River IFIM Study. Reach Number 1, Pleasant River Lake to Worcester Camp, Riffles. Changes in wetted area and usable habitat area (sq. ft.) as a function of flow (see also Figure 2).

	Area per 1,000 feet of stream				Total habitat area	
Discharge (cfs)	YOY	Parr	Wetted Area		YOY	Parr
2	9031	8416	20599		25874	24112
4	10733	10687	23051		30751	30619
6	11996	12237	23659		34370	35060
8	12515	13208	23926		35856	37840
10	12756	13943	24146		36547	39946
12	12806	14480	24323		36688	41484
14	12689	14791	24454		36353	42377
16	12510	15024	24569		35841	43044
18	12284	15216	24685		35194	43593
20	12004	15225	24762		34390	43620
30	10838	15534	25209		31051	44505
40	9833	14786	25628		28171	42362
50	9115	13896	26615		26114	39812
60	8548	13107	27290		24489	37551
70	8080	12296	28029		23151	35229
80	7786	11616	28884		22306	33281
90	7408	10851	29309		21224	31088

Table 7. Pleasant River IFIM Study. Reach Number 2, Worcester Camp to Crebo Bridge, coarse substrate riffle. Changes in wetted area and usable habitat area (sq. ft.) as a function of flow (see also Figure 3).

	Area per 1,000 feet of stream			**Total habitat area**
Discharge (cfs)	**Spawning**	**Wetted Area**		**Spawning**
2	433	19841		1612
4	1157	21160		4310
6	2142	21980		7977
8	3627	22641		13511
10	4718	24198		17573
12	5724	25251		21319
14	5785	25479		21544
16	6119	25790		22789
18	6676	26017		24866
20	6729	26431		25063
32	7140	29599		26594
44	8517	30454		31723
56	9186	31264		34214
68	8946	33640		33319
80	8332	34867		31032
92	7643	35958		28466
104	6843	36627		25487

Table 8. Pleasant River IFIM Study. Reach Number 2, Worcester Camp to Crebo Bridge moderate gradient run. Changes in wetted area and usable habitat area (sq. ft.) as a function of flow (see also Figure 4).

	Area per 1,000 feet of stream				Total habitat area	
Discharge (cfs)	**YOY**	**Parr**	**Wetted Area**		**YOY**	**Parr**
2.5	12448	12323	27294		98517	97532
5	13587	14801	28648		107531	117144
7.5	14126	15831	29372		111795	125291
10	14499	16408	29863		114754	129857
12.5	14795	16795	30128		117092	132924
15	15041	17090	30369		119039	135258
17.5	15109	17307	30539		119580	136972
20	15124	17490	30631		119694	138427
22.5	15002	17589	30711		118731	139205
25	14789	17632	30785		117046	139543
40	12755	17102	31148		100948	135349
55	10643	15026	31328		84233	118923
70	8728	12465	31465		69077	98650
85	7241	10226	31590		57308	80934
100	6073	8248	31706		48064	65279
115	5068	6703	31806		40110	53050
130	4304	5660	31898		34064	44795

Table 9. Pleasant River IFIM Study. Reach Number 3, Crebo Bridge to Saco Falls, glide habitat. Changes in wetted area and usable habitat area (sq. ft.) as a function of flow (see also Figure 5).

	Area per 1,000 feet of stream		Total habitat area
Discharge (cfs)	Parr	Wetted Area	Parr
4	9240	20227	57194
8	10173	21790	62966
12	10187	24212	63053
16	9769	26459	60465
20	8839	27127	54708
24	7626	27636	47202
28	6327	27904	39159
32	5104	28030	31591
36	4263	28145	26388
40	3427	28270	21214
60	1433	28975	8870
80	916	31566	5667
100	864	31775	5348
120	857	32356	5307
140	766	32525	4741
160	707	32525	4377
180	630	32525	3901

Table 10. Pleasant River IFIM Study. Reach Number 4, Saco Falls to Western Little River, riffle habitat. Changes in wetted area and usable habitat area as a function of flow (see also Figure 6).

Transect 5a

	Area per 1,000 feet of stream			
Discharge (cfs)	*YOY*	*Parr*	*Spawning*	*Wetted Area*
0	*0*	*0*	*0*	*7287*
0	*0*	*0*	*0*	*7287*
0	*0*	*0*	*0*	*7287*
1	*1737*	*1732*	*0*	*7287*
2	*1946*	*2560*	*0*	*9582*
2	*1946*	*2560*	*0*	*9582*
3	*2163*	*2975*	*74*	*11422*
4	*2248*	*3219*	*198*	*11539*
4	*2248*	*3219*	*198*	*11642*
5	*2276*	*3422*	*306*	*11642*
9	*2208*	*3936*	*462*	*11979*
13	*1914*	*3966*	*491*	*12243*
20	*1450*	*3626*	*579*	*12686*
30	*1071*	*3014*	*532*	*13305*
40	*918*	*2563*	*343*	*13889*
49	*862*	*2232*	*158*	*14339*
59	*795*	*2061*	*205*	*14896*

Transect 5b

	Area per 1,000 feet of stream			
Discharge (c	*YOY*	*Parr*	*Spawning*	*Wetted Area*
6	*7021*	*8889*	*0*	*38233*
12	*8695*	*12307*	*0*	*47364*
18	*9536*	*14240*	*216*	*49774*
23	*10040*	*15445*	*425*	*50552*
28	*10317*	*16201*	*564*	*51113*
34	*9756*	*16240*	*1245*	*51717*
39	*9630*	*16486*	*1374*	*52119*
44	*9466*	*16550*	*1510*	*52421*
49	*9420*	*16908*	*1592*	*55216*
55	*9342*	*17209*	*1692*	*56511*
81	*8483*	*17461*	*2258*	*59133*
107	*7409*	*16498*	*2503*	*60056*
130	*7034*	*15460*	*1808*	*61062*
150	*6700*	*14726*	*1170*	*61697*
170	*6268*	*14102*	*975*	*62065*
191	*5850*	*13258*	*756*	*62404*
211	*5378*	*12160*	*584*	*62742*

Transects 5a and 5b combined

	Area per 1,000 feet of stream					**Total habitat area**		
Net Discharge (cfs)	**YOY**	**Parr**	***Spawning***	**Wetted Area**		**YOY**	**Parr**	**Spawning**
6	7021	8889	0	45520		27849	35258	0
12	8695	12307	0	54651		34491	48818	0
18	9536	14240	216	57061		37824	56484	857
24	11776	17177	425	57839		46712	68134	1687
30	12263	18761	564	60695		48644	74417	2236
36	11702	18800	1245	61299		46419	74571	4939
42	11793	19461	1448	63541		46779	77196	5745
48	11715	19769	1709	63960		46469	78417	6777
53	11669	20128	1791	66858		46286	79839	7103
60	11618	20631	1998	68153		46085	81834	7926
90	10692	21397	2721	71112		42409	84873	10792
120	9323	20463	2993	72299		36979	81170	11873
150	8484	19086	2387	73748		33654	75709	9468
180	7771	17741	1702	75001		30823	70371	6752
210	7186	16666	1318	75955		28504	66106	5228
240	6712	15490	914	76743		26625	61443	3626
270	6173	14222	789	77638		24485	56412	3130

Table 11. Pleasant River IFIM Study. Reach Number 5, Western Little River to Columbia Falls, coarse substrate spawning riffle. Changes in wetted area and usable habitat area (sq. ft.) as a function of flow (see also Figure 7).

	Area per 1,000 feet of stream		Total habitat area
Discharge (cfs)	**Spawning**	**Wetted Area**	**Spawning**
8	0	83734	0
16	309	91653	808
24	1663	92665	4350
32	3548	93340	9281
40	6994	93946	18297
48	9847	94284	25761
56	14584	94623	38152
64	18830	94893	49260
72	24589	95164	64326
80	28879	95367	75548
120	44158	95843	115518
160	50555	96230	132252
200	49283	96639	128925
240	43542	97026	113907
280	36988	97592	96761
320	31504	98192	82415
360	26866	98753	70281

Table 12. Pleasant River IFIM Study. Reach Number 5, Western Little River to Columbia Falls, mixed substrate riffle. Changes in wetted area and usable habitat area (sq. ft.) as a function of flow (see also Figure 8).

	Area per 1,000 feet of stream				Total habitat area		
Discharge (cfs)	**YOY**	**Parr**	**Spawning**	**Wetted Area**	**Parr**	**Spawning**	**YOY**
10	23909	19506	2333	54688	21104	2525	25867
20	28824	27644	6146	65809	29909	6649	31186
30	29156	31924	10171	69545	34540	11004	31545
40	28180	33869	13040	71460	36644	14109	30488
50	26885	34579	15404	72964	37411	16666	29087
60	25501	34254	17023	74130	37060	18417	27591
70	24295	33732	17979	75031	36495	19452	26285
80	23065	32718	17954	75587	35398	19425	24954
90	24295	34456	18222	76145	37279	19715	26285
100	23222	33314	18481	76555	36043	19995	25124
150	18467	28663	17650	79326	31011	19096	19980
200	14808	24705	15216	80979	26729	16463	16021
250	12042	21032	12122	82316	22755	13115	13029
300	10115	17558	9287	83242	18996	10048	10944
350	8706	14263	7252	83876	15431	7846	9419
400	7563	11503	5909	84404	12445	6393	8183
450	6516	9325	4945	85064	10089	5350	7050

Table 13. Pleasant River IFIM study. Summary of estimated total habitat available across a range of flows in each stream reach.
Data based on habit type length estimates provided by MASA.

Reach Number 1
riffle

Discharge (cfs)	YOY total	Parr total
2	25874	24112
4	30751	30619
6	34370	35060
8	35856	37840
10	36547	39946
12	36688	41484
14	36353	42377
16	35841	43044
18	35194	43593
20	34390	43620
30	31051	44505
40	28171	42362
50	26114	39812
60	24489	37551
70	23151	35229
80	22306	33281
90	21224	31088

Reach Number 2
run

Discharge (cfs)	YOY total	Parr total
2	98517	97532
4	107531	117144
6	111795	125291
8	114754	129857
10	117092	132924
12	119039	135258
14	119580	136972
16	119694	138427
18	118731	139205
20	117046	139543
30	100948	135349
40	84233	118923
50	69077	98650
60	57308	80934
70	48064	65279
80	40110	53050
90	34064	44795

Reach Number 2
spawning riffle

Discharge (cfs)	Spawning total
2	1612
4	4310
6	7977
8	13511
10	17573
12	21319
14	21544
16	22789
18	24866
20	25063
30	26594
40	31723
50	34214
60	33319
70	31032
80	28466
90	25487

Reach Number 3
glide

Discharge (cfs)	Parr total
4	57194
8	62966
12	63053
16	60465
20	54708
24	47202
28	39159
32	31591
36	26388
40	21214
60	8870
80	5667
100	5348
120	5307
140	4741
160	4377
180	3901

Reach Number 4
riffle

Discharge (cfs)	YOY total	Parr total	Spawning total
6	27849	35258	0
12	34491	48818	0
18	37824	56484	857
24	46712	68134	1687
30	48644	74417	2236
36	46419	74571	4939
42	46779	77196	5745
48	46469	78417	6777
53	46286	79839	7103
60	46085	81834	7926
90	42409	84873	10792
120	36979	81170	11873
150	33654	75709	9468
180	30823	70371	6752
210	28504	66106	5228
240	26625	61443	3626
270	24485	56412	3130

Reach Number 5
mixed riffle

Discharge (cfs)	YOY total	Parr total	Spawning total
6	25867	21104	2525
12	31186	29909	6649
18	31545	34540	11004
24	30488	36644	14109
30	29087	37411	16666
36	27591	37060	18417
42	26285	36495	19452
48	24954	35398	19425
53	26285	37279	19715
60	25124	36043	19995
90	19980	31011	19096
120	16021	26729	16463
150	13029	22755	13115
180	10944	18996	10048
210	9419	15431	7846
240	8183	12445	6393
270	7050	10089	5350

Reach Number 5
spawning riffle

Discharge (cfs)	Spawning total
8	0
16	808
24	4350
32	9281
40	18297
48	25761
56	38152
64	49260
72	64326
80	75548
120	115518
160	132252
200	128925
240	113907
280	96761
320	82415
360	70281

Table 14. Times of occurrence of lifestages of Atlantic salmon in the Pleasant River relative to the magnitude of monthly median flows. (Upper case "X" indicate low flow month for respective lifestages).

Month	adult	spawning and incubation	YOY	parr	Median Discharge (cfs) @ Saco Falls
January	x	x		x	89.0
February	x	x		x	116.5
March	x	x		x	148.0
April	x	x		x	270.5
May	x	x	x	x	155.5
June	x		x	x	87.0
July	x		x	x	53.5
August	x		x	x	50.0
September	**X**		**X**	**X**	44.0
October	x	**X**	x	x	67.0
November	x	x	x	x	139.0
December	x	x	x	x	120.0

FIGURES

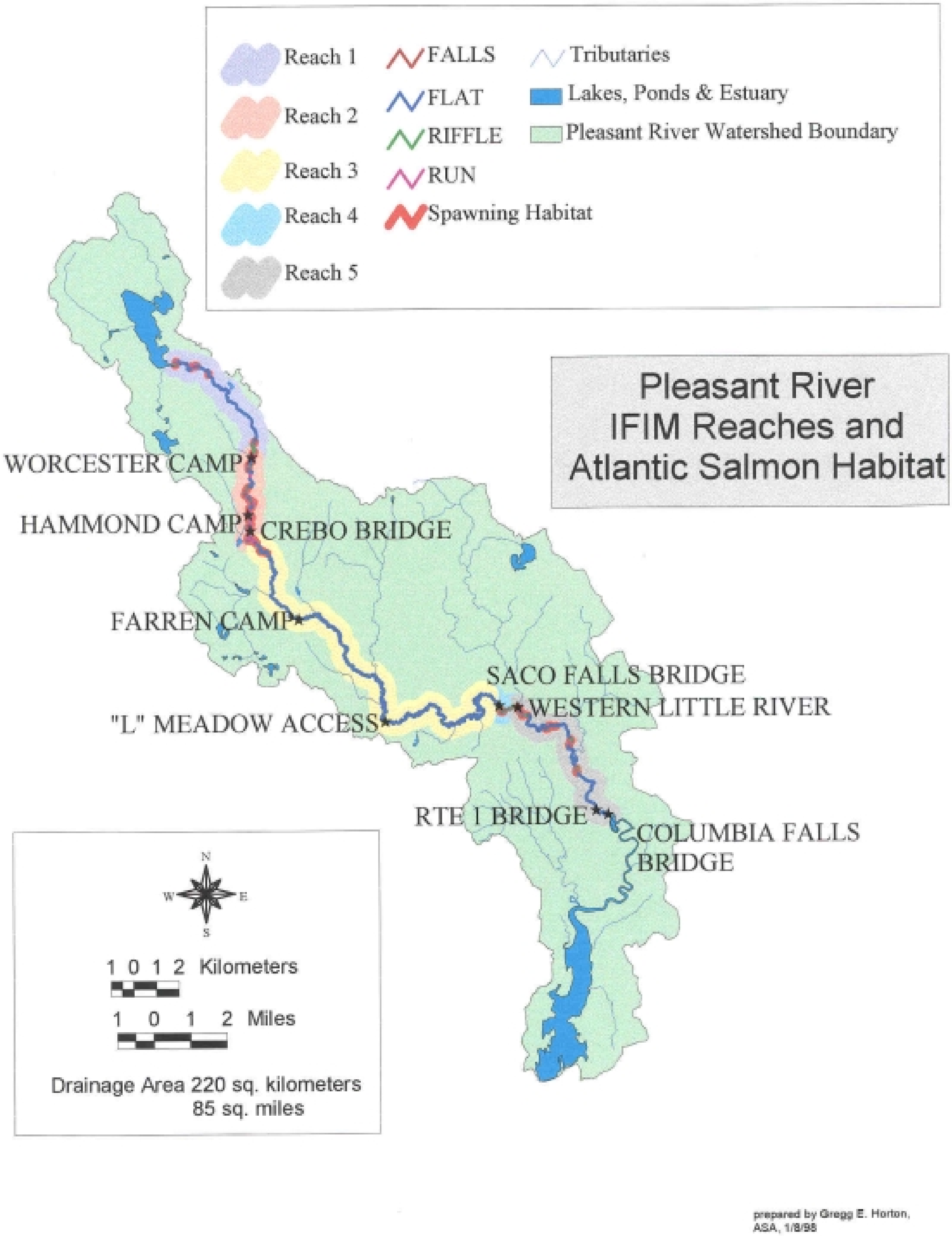

Reach 1
Reach 2
Reach 3
Reach 4
Reach 5
FALLS
FLAT
RIFFLE
RUN
Spawning Habitat
Tributaries
Lakes, Ponds & Estuary
Pleasant River Watershed Boundary
Pleasant River
IFIM Reaches and
Atlantic Salmon Habitat
WORCESTER CAMP
HAMMOND CAMP
CREBO BRIDGE
FARREN CAMP
SACO FALLS BRIDGE
WESTERN LITTLE RIVER
"L" MEADOW ACCESS
RTE 1 BRIDGE
COLUMBIA FALLS
BRIDGE
N
W
E
S
1 0 1 2 Kilometers
1 0 1 2 Miles
Drainage Area 220 sq. kilometers
85 sq. miles
prepared by Gregg E. Horton,
ASA, 1/8/98

Figure 2. Pleasant River IFIM Study. Habitat and wetted area vs. flow relationship in Reach No. 1, Pleasant River Lake to Worcester Camp, riffles (Sq Ft per 1,000 ft of stream).

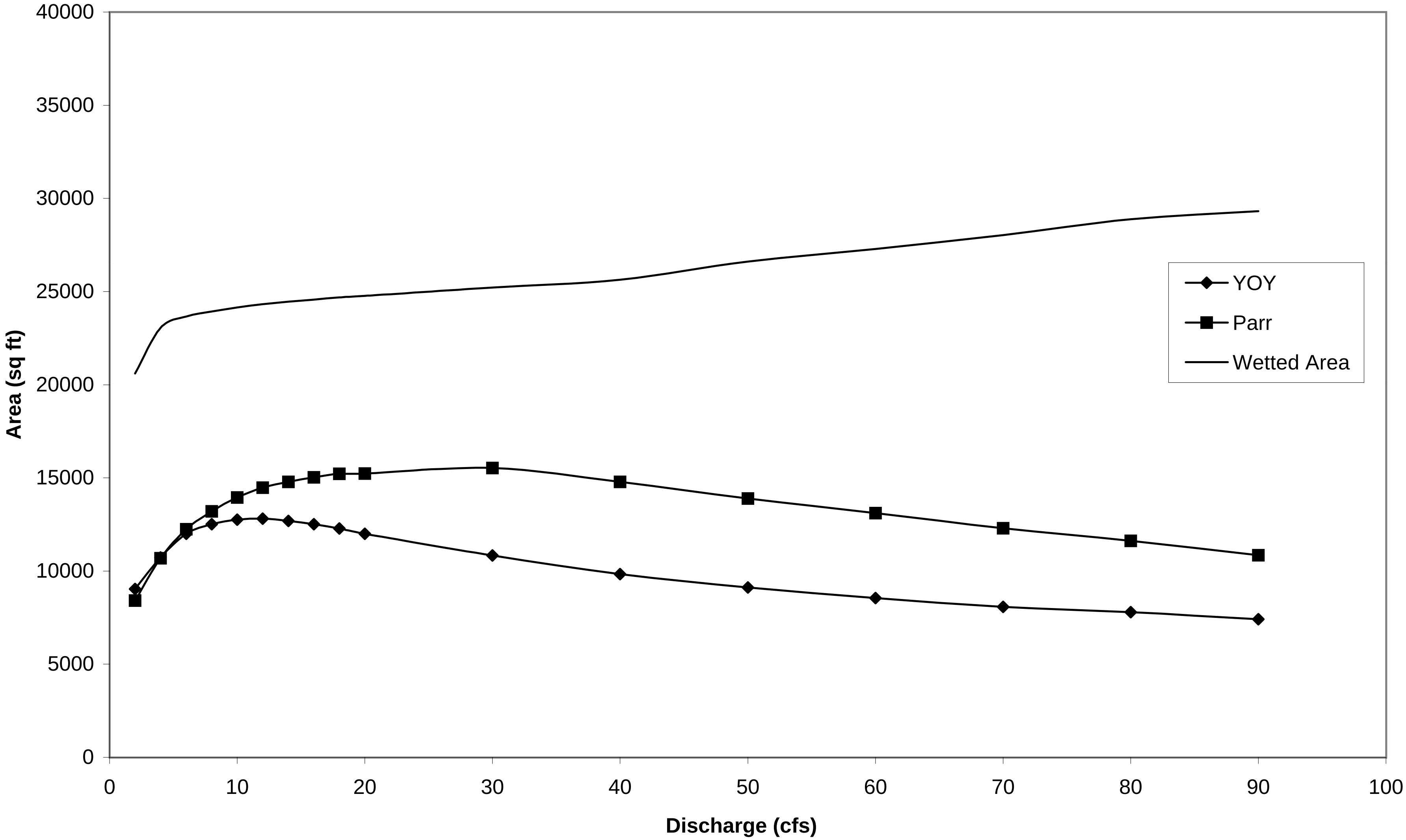


Figure 3. Pleasant River IFIM Study. Habitat and wetted area vs. flow relationship in Reach No. 2, Worcester Camp to Crebo Bridge, moderate gradient run, (Sq Ft per 1,000 ft of stream).

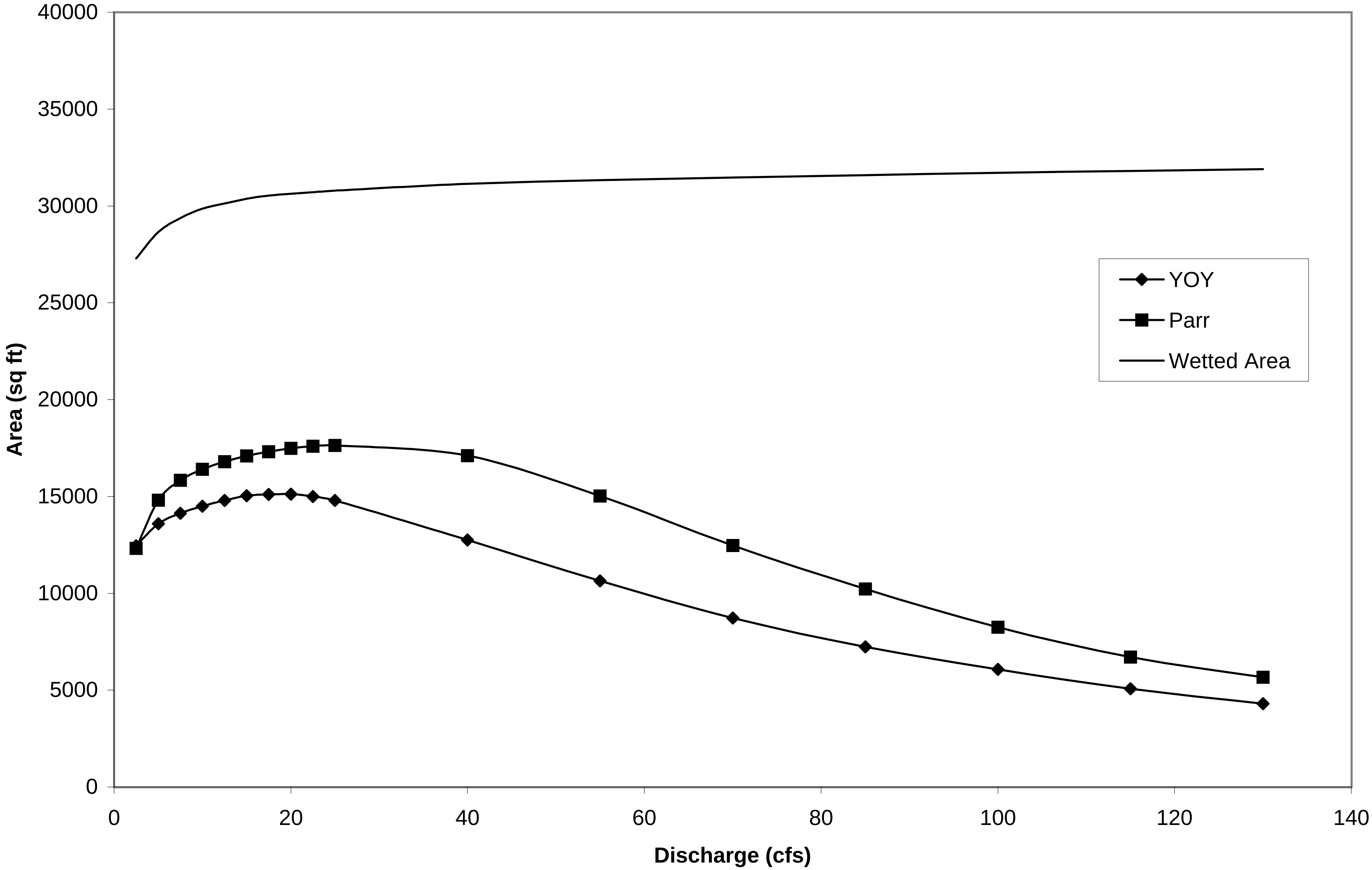


Figure 4. Pleasant River IFIM Study. Habitat and wetted area vs. flow relationship in Reach No. 2, Worcester Camp to Crebo Bridge, coarse substrate, (Sq Ft per 1,000 ft of stream).

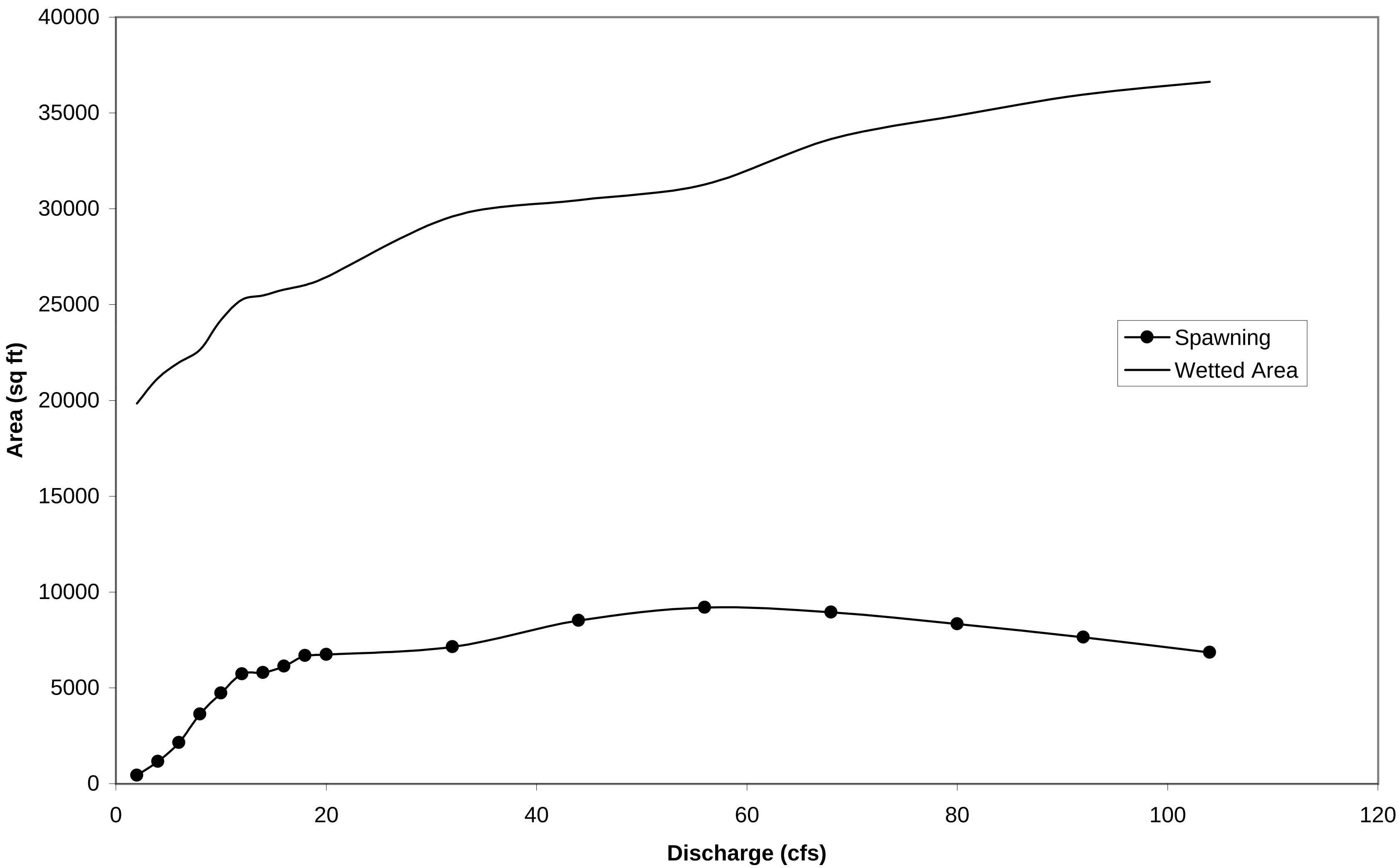


Figure 5. Pleasant River IFIM Study, Habitat and wetted area vs. flow relationship in Reach No. 3, Crebo Bridge to Saco Falls, riffles (Sq Ft per 1,000 ft of stream).

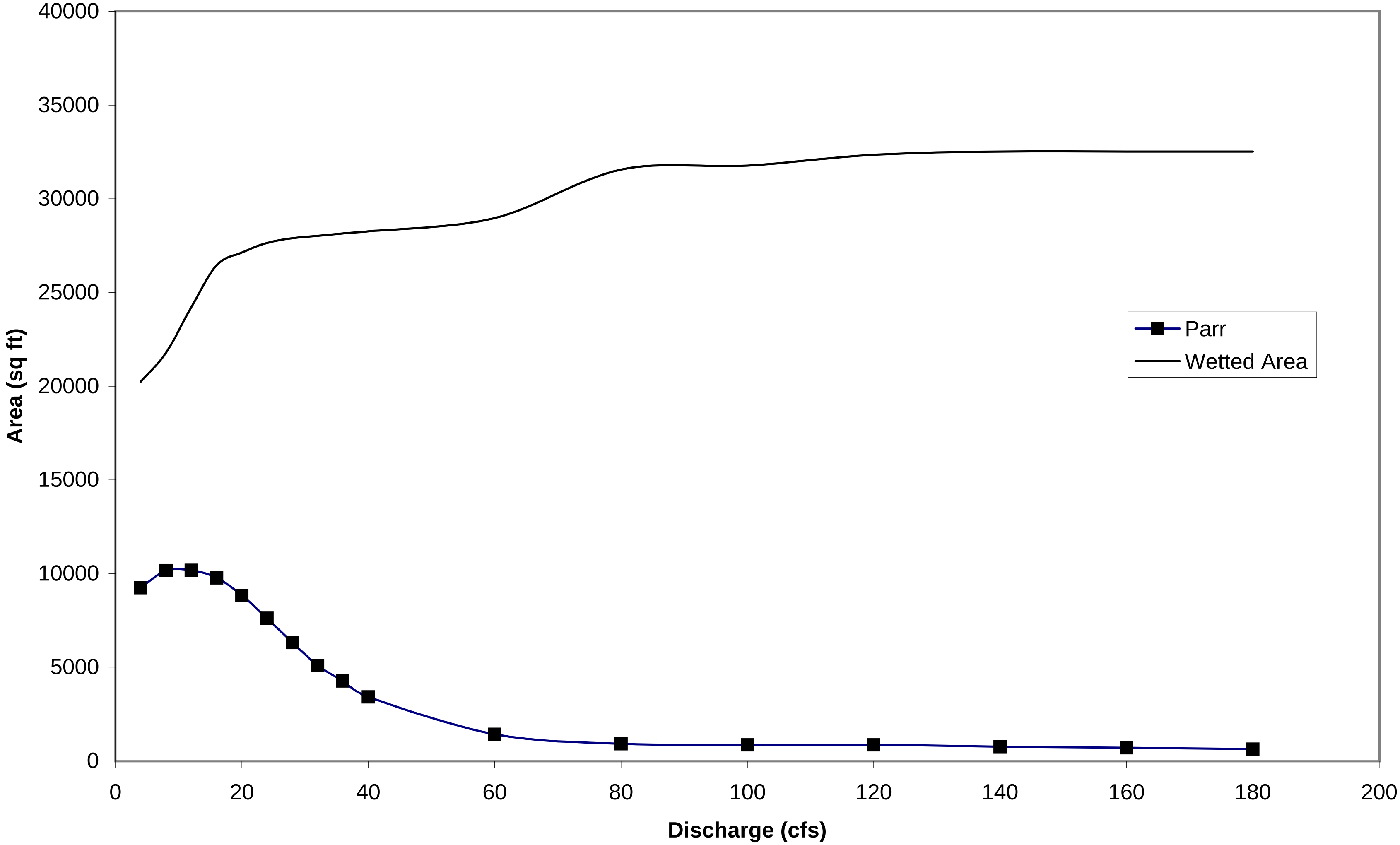


Figure 6. Pleasant River IFIM Study. Habitat and wetted area vs. flow relationship in Reach No. 4, Saco Falls to Western Little River, riffles (Sq Ft per 1,000 ft of stream).

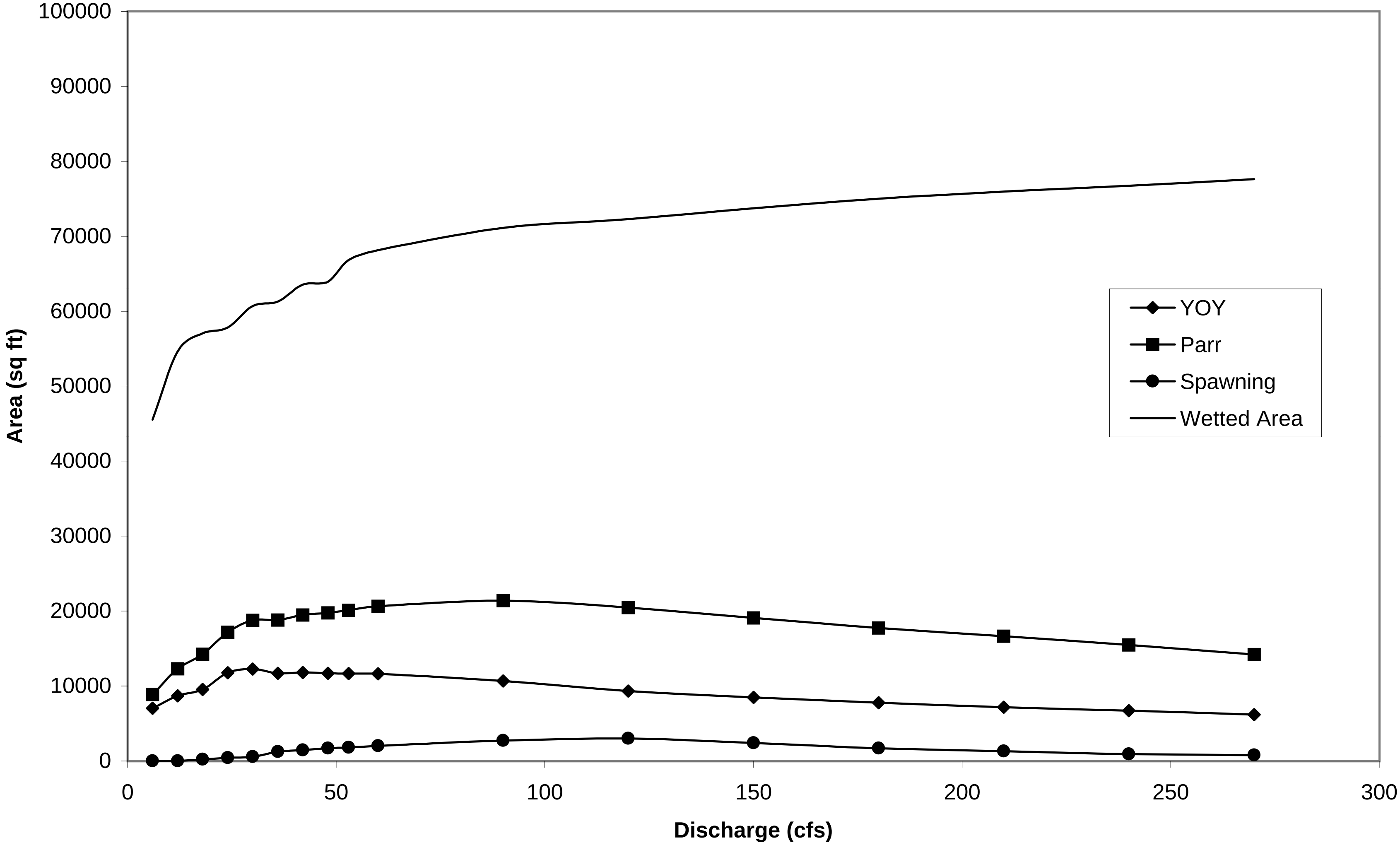


Figure 7. Pleasant River IFIM Study. Habitat and wetted area vs. flow relationship in Reach No. 5, Western Little River to Columbia Falls, coarse substrate, spawning riffles (Sq Ft per 1,000 ft of stream).

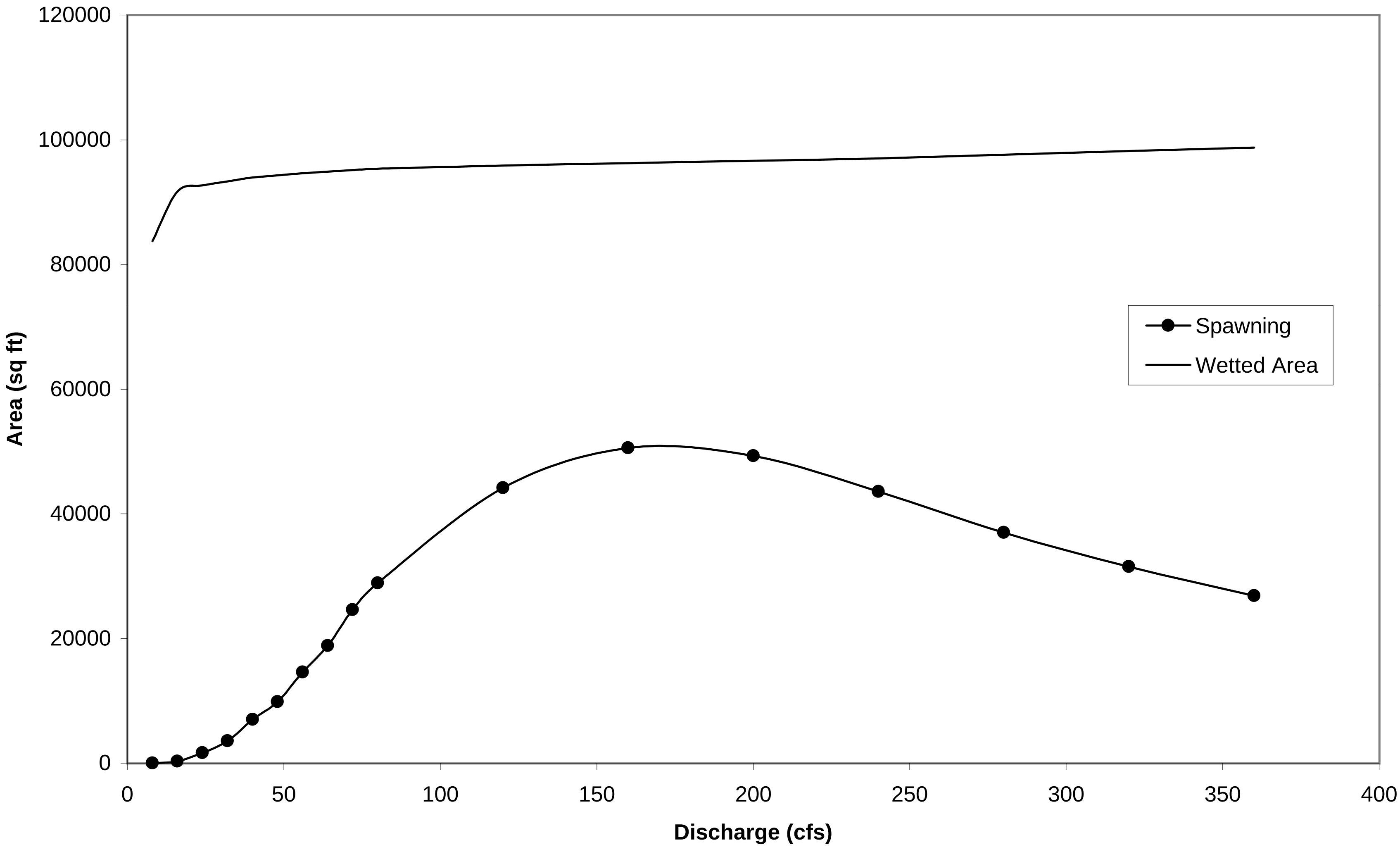
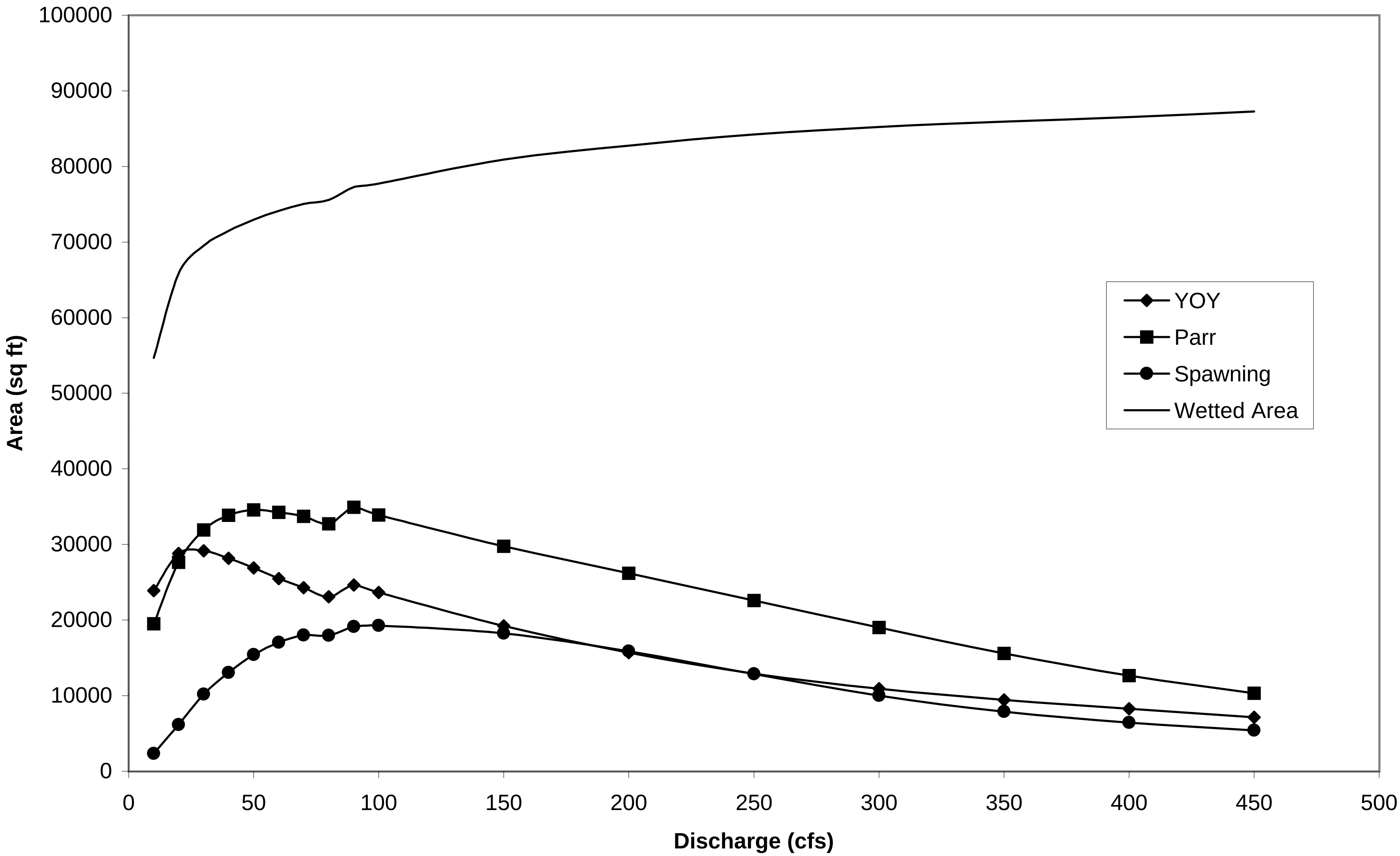


Figure 8. Pleasant River IFIM Study. Habitat and wetted area vs. flow relationship in Reach No. 5, Western Little River to Columbia Falls, riffles (Sq Ft per 1,000 ft of stream).



APPENDIX A

TECHNICAL TEAM STUDY SCOPING

(Omitted for brevity – available upon request)

APPENDIX B: HABITAT SUITABILITY INDEX DATA

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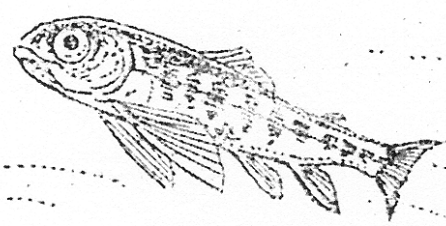
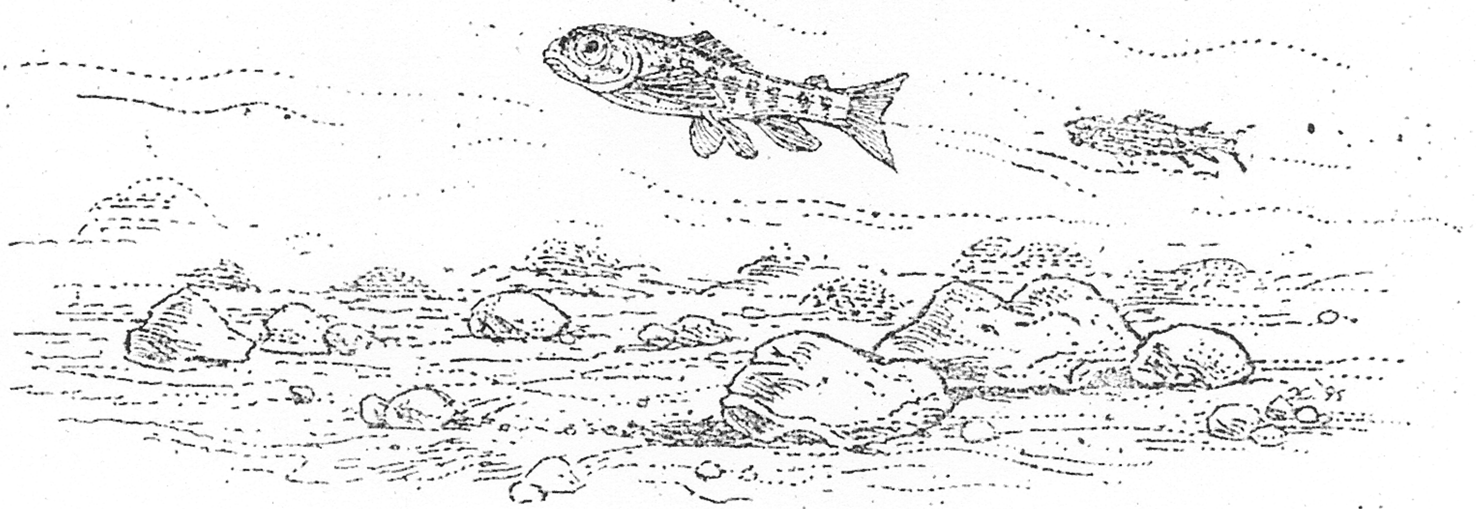
BIOLOGICAL SCIENCE REPORT 3



HABITAT SUITABILITY INDEX MODELS: NONMIGRATORY FRESHWATER LIFE STAGES OF ATLANTIC SALMON



that move over this habitat. In Peterson's (1978) study, the particle size composition was 0–3% fine sand (0.06–0.5 mm), 10–15% coarse sand (>0.5–2.2 mm), 40–50% pebble (>2.2–22 mm), and 40–60% cobble (>22–256 mm). Spawners preferred gravel of 20–30 mm diameter (Crisp and Carling 1989). The substrate composition of the redds of landlocked Atlantic salmon included higher percentages of intermediate-size particles (Warner 1963). The landlocked fish, which are smaller than the sea-run fish, may not be capable of moving the larger particles.

Because juvenile salmon occur in the riffle area of streams, they are likely to be found above substrate containing sand, gravel, and cobble rather than silt. In one stream, Atlantic salmon fry selected a substrate classified as 4.8, based on an index in which 3 represents fines and detritus; 4, sand; 5, gravel; and 6, cobble (Trial and Stanley 1984). In two Canadian streams, the most preferred substrate had an index of 4.5–5.5 for fry and parr (DeGraff and Bain 1986). In eight other Canadian streams, this index was 5.6 for fry, 5.9 for small parr, and 6.4 for large parr, indicating selection of a coarser substrate as juveniles grow (Morantz et al. 1987). During their first year, juveniles preferred gravel substrate (16–64 mm), whereas yearling parr preferred a boulder and rubble substrate where diameters were greater than 260 mm (Symons and Heland 1978). Gibson (1993) concluded that fry are most common where there is a pebbly bottom, and parr over coarser substrate. In a Norwegian stream, fry were observed over a gravel to boulder substrate, and parr occupied a wider range of substrate types (Heggenes et al. 1990).

Depth, velocity, and substrate are interdependent. Substrate is related to velocity, and velocity is affected by depth. It is difficult to determine whether juveniles, as they grow, select larger substrates, faster velocities, or deeper areas with similar substrate and velocity. However, all variables seem to be differentially selected by fry and parr. Our SI's were constructed so that pebble-size substrates were best for fry and cobble substrates best for parr.

Sedimentation into the spaces between pebbles and cobble interferes with the use of this space as shelter for young Atlantic salmon and decreases their survival rate in summer (McCrimmon 1954). In winter, siltation and suspended debris within the substrate are also important because fish hide in spaces under rocks (Cunjak 1988). Such sedimentation obviously also affects benthic production and reproductive success.

Atlantic salmon typically occur in clear streams and depend on transparent water for site-feeding. Turbidities of 40 nephelometric turbidity units (NTU) or less are considered to represent clear water that is highly suitable for feeding. Survival of fry and parr was highest in stream segments with the lowest base turbidities (McCrimmon 1954). As turbidities increase to 100 NTU, progressive interference with sight feeding and growth is possible. In the laboratory, coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) grew fastest in clear water; growth was inhibited at 45–50 NTU (Sigler et al. 1984). In some tests, 38–49 NTU did not inhibit growth, and in other tests turbidity as low as 25 NTU inhibited growth. When coho salmon were exposed to turbidities of 30 and 60 NTU, territoriality deteriorated and prey capture rates declined (Berg and Northcote 1985). Coho salmon avoided turbidity of 70 NTU (Bisson and Bilby 1982). Episodes of high turbidity seem to do no harm, and turbidity alone correlated poorly with effects of suspended sediments on fish (Newcombe and MacDonald 1991). Relatively low turbidities over long periods caused reduced feeding in several species of salmonids (Newcombe and MacDonald 1991). Turbidities exceeding 1,150 standard units, measured with a photometer during fall freshets, did not injure or kill Atlantic salmon fry or parr (McCrimmon 1954).

The SI for turbidity was based on effects on other species of salmonids, primarily as reported in the review by Newcombe and MacDonald (1991).

Habitat Suitability Index (HSI) Models

Applicability of the Models

Potential users of the HSI model for Atlantic salmon can have confidence in applying the model in habitats where the model was developed and tested. Considerable effort has gone into validating the model, especially for the more important variables. The model is equally applicable to anadromous and landlocked populations of juvenile Atlantic salmon. We recommend the use of this HSI model to help formulate expert opinion on habitat quality. However, we caution that the model is a hypothesis describing a simplified version of complex interrelationships within a seasonally dynamic environment. In addition, the model concerns a species with shifting habitat requirements, complex behaviors, and a long life cycle. Furthermore, this HSI model does not consider toxic chemicals, which if present may limit the application to predicting what habitat quality would be if the contaminant were removed.

Geographical Area

The HSI model was designed for Atlantic salmon in streams of New England and the Canadian maritimes of temperate North America. The model applies to embryos, fry, and parr in streams and to adults only in regard to the selection of spawning sites. European populations share many of the same characteristics as the North American populations, and the model could probably be applied to European populations with little modification.

Season

The water quality, fry, and parr components of the HSI model are designed to evaluate the summer habitat of juvenile Atlantic salmon during base flow, when the extent of the available habitat is limited. The reproductive component obviously applies during the fall period. Winter habitat may be particularly important to the survival of Atlantic salmon; for example, low winter discharge significantly affects juvenile survival (Gibson and Myers 1988). Except for temperature and ice, the habitat occupied by juveniles differs only slightly from summer habitat (Rimmer et al. 1984; Cunjak 1988). Although survival is correlated with winter air temperatures and water levels (Chadwick 1982), no measurements link specific winter conditions to embryo or juvenile survival.

Habitat Types

The HSI model applies to embryos and juveniles in freshwater, riverine (lotic) habitat. The model describes the area where spawning and egg incubation occur, as well as nearby nursery areas for juveniles. The model does not consider the lake and marine feeding grounds of adults or any habitat characteristics critical to successful downstream or upstream migration in estuaries or freshwater streams. The model has the most validity when applied to the streams in which it was tested or to similar streams. Tests were done in streams ranging from small brooks to the mainstem of major rivers, such as the St. John River in New Brunswick.

Minimum Habitat Area

In HSI models, the minimum habitat area usually includes egg incubation areas, nursery and juvenile feeding grounds, and adult feeding grounds. For Atlantic salmon, the usual definition of minimum habitat area does not apply because the habitats for the different life stages usually are not contiguous. Of critical importance to Atlantic salmon populations is free passage between the different habitats, unobstructed by dams or interception by excessive fisheries.

The area of habitat used by Atlantic salmon varies considerably. Some stocks of landlocked Atlantic salmon exist within a single river system in which spawning, nursery, and feeding areas are within a few kilometers of each other, for example, the West Branch of the Penobscot River in Maine (Warner and Havey 1985). At the opposite extreme, some populations have nursery grounds in small streams in Portugal, and the adults feed in Arctic waters off the coast of Baffin Island in North America (Netboy 1974). The minimum habitat area for the juvenile life stages is poorly defined, in part because little information is published on distances for the dispersion of fry and parr. Dispersal occurs rapidly in spring as fry emerge from the redd and move predominantly downstream (McKenzie and Moring 1988; Gustafson-Greenwood and Moring 1990). Parr then disperse gradually over the summer to occupy all suitable stream habitats. In winter, older parr move from the riffles in streams into slower waters (Rimmer et al. 1984). Dispersal was faster for parr planted in deep, slow water than for parr planted in their preferred habitat of fast-moving water (Heggenes and Borgstrom 1991). For most of these dispersal phases, the extent of movements is unknown.

Verification Level

Originally, the SI's and HSI model presented here were derived from literature values and initially tested in Maine streams (Trial and Stanley 1984; Trial et al. 1984). Suitability indices for water depth, velocity, and substrate were independently developed and tested in Canadian streams (Morantz et al. 1987). A third test for validation was done in Maine streams (Trial 1989). A fourth test was done in which Trial (1989) analyzed data collected in New Brunswick by Francis (1980) and Trial (1989). Recently, SI's developed for Newfoundland rivers were tested and found to consistently predict standing crop of fry (Scruton and Gibson 1993).

Trial (1989) formulated four alternative HSI models based on an evaluation of SI's related to velocity, substrate, and depth. Two of the HSI models used SI's from Morantz et al. (1987) from the fry and parr components, and two used SI's from Trial and Stanley (1984). Trial (1989) determined the goodness of fit between the measured variables for habitat selected by juveniles and the SI values. In other words, the cumulative frequency distribution (CFD) of suitability based on habitat selection by fish was compared with the hypothetical CFD. This process was done stepwise for individual SI's and the life stage component indices produced from either the product of the three SI's or their geometric mean. Trial's (1989) test of fry and parr components indicated that the CFD from the SI's in Trial and Stanley (1984) and Morantz et al. (1987) had a more gradual rise to 100% than the CFD from her data on fry in Maine streams. The apparent lack of fit of the components was expected because the SI's were overestimates of the optimal range of each habitat variable (Trial 1989).

In a second test, Trial (1989) found that the joint probabilities and geometric means for the fry component index were correlated with the density of fry. The two ways of calculating component indices did not affect the ranking of the sites—the ranks of the alternative component indices were correlated with the rank of fry density at 16 sites. In contrast, none of the parr component models correlated with parr densities, probably because other variables, such as cover, were important. For total numbers of juveniles, three of the four HSI models were correlated with population density, and only the model based on joint probability and the SI's by Morantz et al. (1987) was not correlated.

These tests of HSI models verified the HSI approach toward evaluating habitat and validated some of the SI's, especially for the water velocity, depth, and substrate of fry. These tests measured density, abundance, or site selection as an indicator of carrying capacity. In general, the microhabitat used within any one stream was narrower than predicted by the models, whereas the range of habitats used among streams was predicted accurately. Scruton and Gibson (1993) noted that SI's are more useful if derived from macrohabitat measurements (e.g., stream width) rather than microhabitat (e.g., variables measured at location of individual fish).

In tests of HSI models by Trial (1989), the reproductive component was based on water quality and stream order. Thus, the complete reproductive component, which consists of variables for depth, velocity, spawning temperature, incubation temperature in winter, stream order, and dominant substrate (Trial and Stanley 1984), was not tested adequately.

The models tested by Trial (1989) did not include food availability because of the difficulty in sampling food abundance for an animal with opportunistic feeding habits. A surrogate measure for food might be possible, based on variables related to the productivity of food of salmonids, such as alkalinity and conductivity (McFadden and Cooper 1962; Cooper and Scherer 1967).

Model Description

The implicit assumption of HSI models is that habitat with high HSI values has high carrying capacity and high productivity potential. These models were developed to predict the effects of environmental changes by relating environmental conditions to carrying capacity (U.S. Fish and Wildlife Service 1981). The aquatic and fish species HSI models provide a systematic method for evaluating projects that may alter the habitat of indicator species.

Life Stage Component Indices

The previously published model (Trial and Stanley 1984) defined parr component suitability as the geometric mean of the SI's for velocity, depth, and substrate. A geometric mean increases the most when the individual variable with the lowest value is increased. In contrast, an arithmetic mean changes the same amount for a fixed amount of increase in a single variable, regardless of which variable is increased. We describe component models in which the quality of holding or redd sites is based on multiplication of three variables (velocity, depth, and substrate) with values on a scale of 0 to 1.0. If the SI for a variable is considered to be a probability of habitat utility, then the component suitability would be a product of the individual variable values. We believe this "joint probability" approach for combining velocity, depth, and substrate suitabilities is biologically the most conservative approach for modeling life stage suitabilities. Because there was no difference in the statistical fit of component indices calculated using the joint probability or the geometric mean (Trial 1989), we chose to use the model that is easiest to use. Bain and Robinson (1988) expressed concern that numerous variables in a geometric mean would result in an unrealistic degree of compensation for the lowest values. Therefore, we used a joint probability approach to calculate component indices.

Water Quality

The water quality component was modeled by a minimum value. Fry (1971) and Brett (1979) recommended this model for limiting and lethal factors. The water quality component in Trial and Stanley's (1984) model consisted of water temperature, pH, turbidity, and minimum oxygen. This component was not correlated with observed densities for fry or parr (Trial 1989). Because the two temperature variables, maximum and average temperature, were within the tolerance range for juvenile Atlantic salmon at all sites, the component index did not discriminate differences. However, temperature might profoundly affect biomass or growth rate, should these be used as end point measurements for testing component indices. Growth of juvenile salmon is highly dependent on temperature (Egglishaw and Shackley 1985).

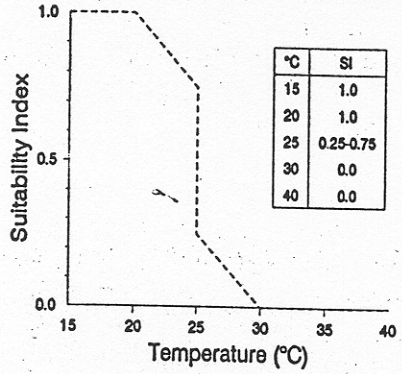
Suitability Index Graphs for Model Variables

The SI for each variable, as a function of the environmental range for that variable, is shown graphically in this section. Habitat suitability indices can be computed with the following SI's, which we modified from Trial and Stanley (1984), based on new literature and Trial (1989). Trial (1989) discussed the assumptions associated with constructing the SI's, and assumptions are also discussed in sections below.

Field use of these SI's requires measurements of key environmental variables. Methods for sampling habitat are described in detail in Terrell et al. (1982), along with some shortcuts applicable to less rigorous studies. A multimillion dollar project with great potential for widespread damage might warrant a full-scale study with multiyear sampling. A local project with probable minimal impact might require only a single visit to the site during summer base flow. Users must decide on the level of sampling required but should not compromise on the methods recommended by Terrell et al. (1982). Alternative methods for gathering data on individual variables were discussed by Hamilton and Bergersen (1984). As with the overall sampling plan, the method selected to measure a variable may be dictated by the scope of the project.

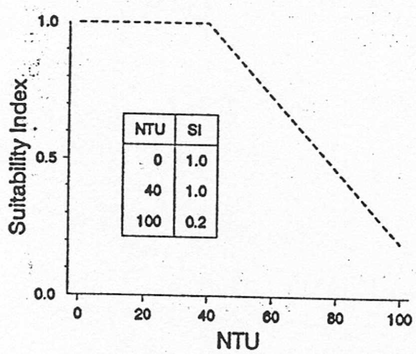
Water Quality Component

V1: Mean maximum daily water temperature for the warmest contiguous 3-day period of summer during base flow, preferably taken from a continuous temperature record (i.e., hydrothermograph).



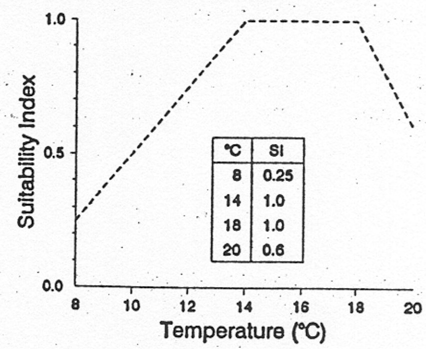
°C	SI
15	1.0
20	1.0
25	0.25-0.75
30	0.0
40	0.0

V3: Mean turbidity based on monthly measurements over as much of the year as possible.



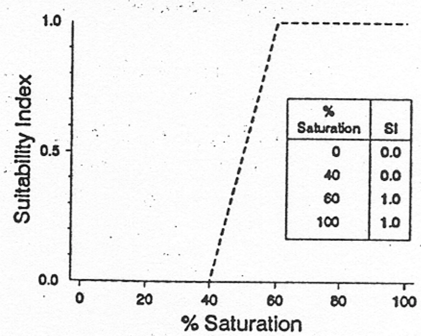
NTU	SI
0	1.0
40	1.0
100	0.2

V2: Mean water temperature for the growing season or summer, preferably taken with a hydrothermograph.



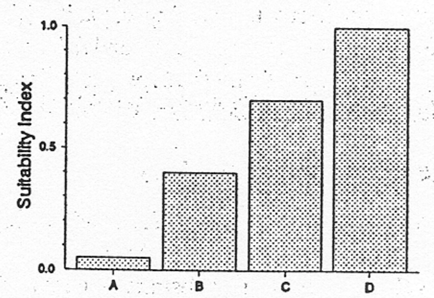
°C	SI
8	0.25
14	1.0
18	1.0
20	0.6

V4: Mean minimum daily oxygen saturation for the 3-day period with the lowest percent saturation during the summer, ideally monitored continuously.



% Saturation	SI
0	0.0
40	0.0
60	1.0
100	1.0

V5: Minimum pH - The frequency at which critical pH levels are reached, as measured during episodes of acid runoff over 3-day periods.

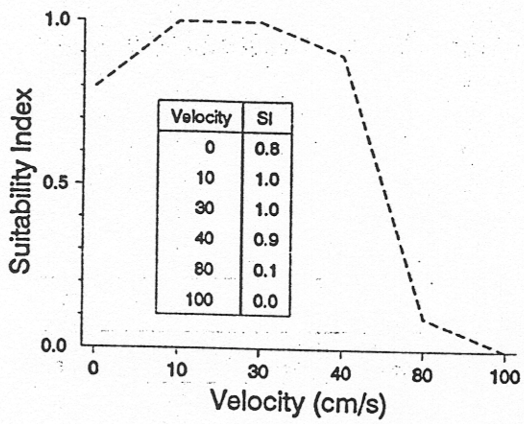


pH Category	Description	S.I.
A	pH below 4.0 at least once annually	0.05
B	pH 4.0 to 5.5 at least once annually	0.40
C	pH occasionally falls below 5.5 but never below 5.0	0.70
D	pH always 5.5 to 6.8	1.00

Fry Component

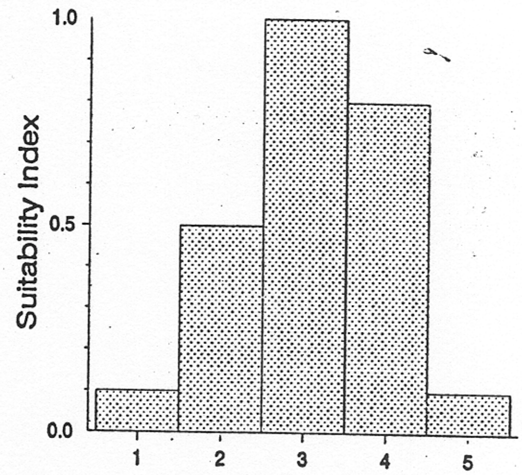
If mean stream depth is greater than 50 cm, divide the stream into fourths. Because fry occur mostly in the shallower sections, average the variables for the two shallowest fourths of the section to arrive at a mean value for each SI of the fry component. In streams shallower than 50 cm, simply average the entire stream.

V6: Mean column velocity for fry during base summer flow. Measuring at a point 0.6 x total depth from the surface approximates mean column velocity.



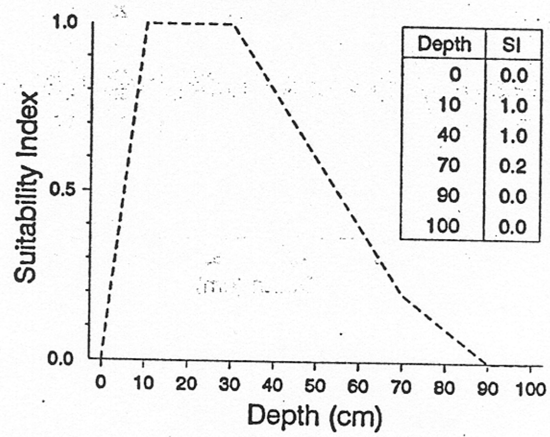
Velocity	SI
0	0.8
10	1.0
30	1.0
40	0.9
80	0.1
100	0.0

V7: Dominant substrate for fry.



Substrate Code	Substrate Type	Size (mm)	SI
1	Fines	< 0.5	0.1
2	Sand	0.5 - 2.2	0.5
3	Pebble-gravel	> 2.2 - 22.2	1.0
4	Cobble	> 22.2 - 256	0.8
5	Boulder	> 256	0.1

V8: Mean depth for fry during base summer flow.

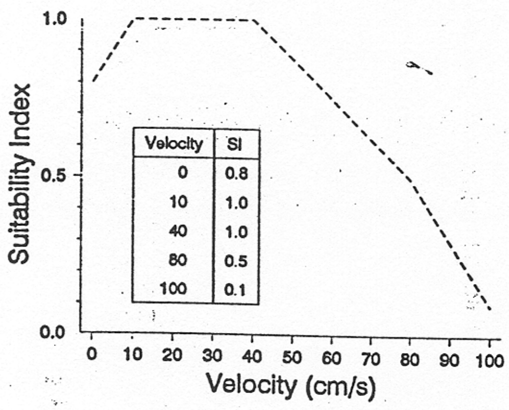


Depth	SI
0	0.0
10	1.0
40	1.0
70	0.2
90	0.0
100	0.0

Parr Component

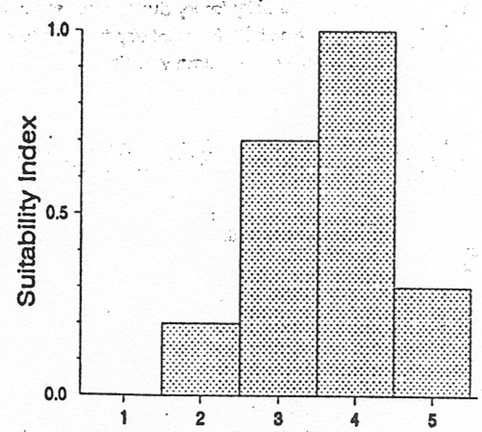
If mean stream depth is over 50 cm, divide the stream into fourths, and average the variables in the two deepest fourths to arrive at the mean value for each SI. In streams shallower than 50 cm, use the mean values for the entire stream.

V9: Mean column velocity for parr during base summer flows.



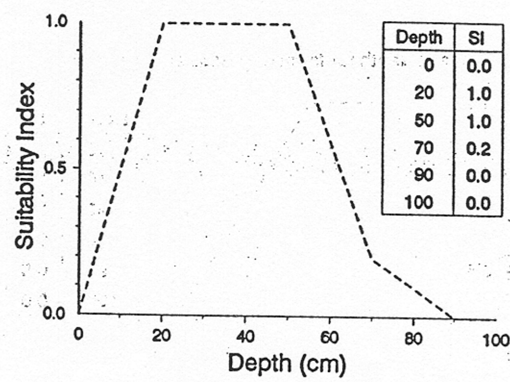
Velocity	SI
0	0.8
10	1.0
40	1.0
80	0.5
100	0.1

V10: Dominant substrate for parr.



Substrate Code	Substrate Type	Size (mm)	SI
1	Fines	< 0.5	0.0
2	Sand	0.5 - 2.2	0.2
3	Pebble-gravel	> 2.2 - 22.2	0.7
4	Cobble	> 22.2 - 256	1.0
5	Boulder	> 256	0.3

V11: Mean depth for parr during base summer flows.

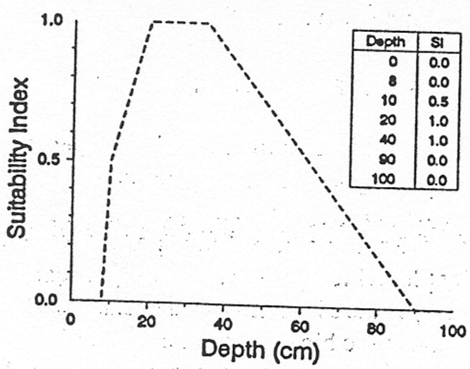


Depth	SI
0	0.0
20	1.0
50	1.0
70	0.2
90	0.0
100	0.0

Reproductive Component

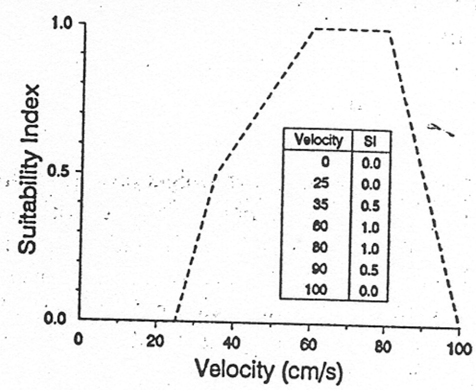
Evaluate at the head or tail of pools only if the substrate material is > 2.2 to 256 mm in diameter and water is at least 15 cm deep. The best time to conduct the field work would be in the fall, when Atlantic salmon are selecting spawning areas. Otherwise, attempt to estimate fall conditions by historical information on seasonal variation.

V12: Mean depth for reproduction at spawning time.



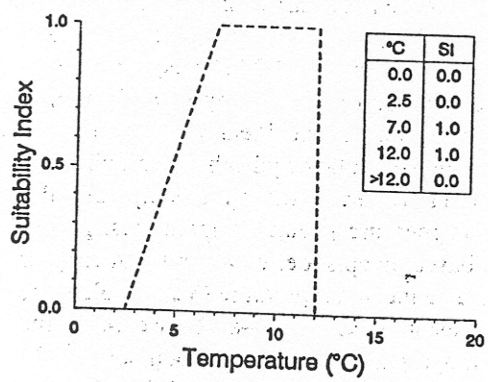
Depth	SI
0	0.0
8	0.0
10	0.5
20	1.0
40	1.0
90	0.0
100	0.0

V13: Mean column velocity for reproduction during fall, or at flow conditions approximating those occurring during fall.



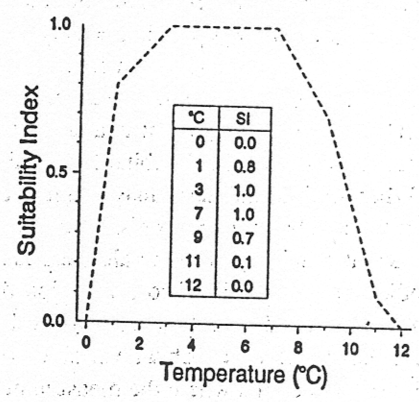
Velocity	SI
0	0.0
25	0.0
35	0.5
60	1.0
80	1.0
90	0.5
100	0.0

V14: Spawning temperature - If water temperature reaches then declines below 12°C in late October and early November, SI=1.0. Spawning will follow the date that water temperature reaches and maintains a temperature between 12° and 7°C.



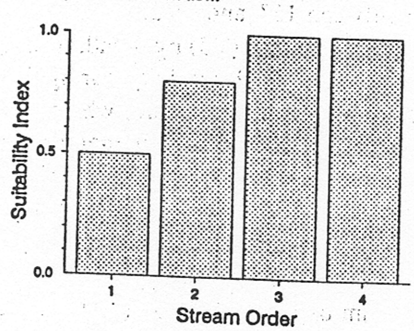
°C	SI
0.0	0.0
2.5	0.0
7.0	1.0
12.0	1.0
>12.0	0.0

V15: Embryo incubation temperature - Average maximum daily temperature for the warmest 2-day period between November 15 and May 1, preferably taken with a hydrothermograph left in the stream over winter.



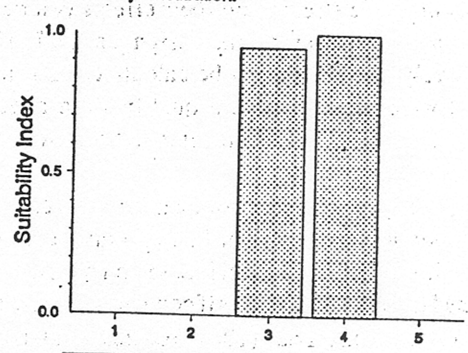
°C	SI
0	0.0
1	0.8
3	1.0
7	1.0
9	0.7
11	0.1
12	0.0

V16: Stream order, based on stream branches having permanent water flow.



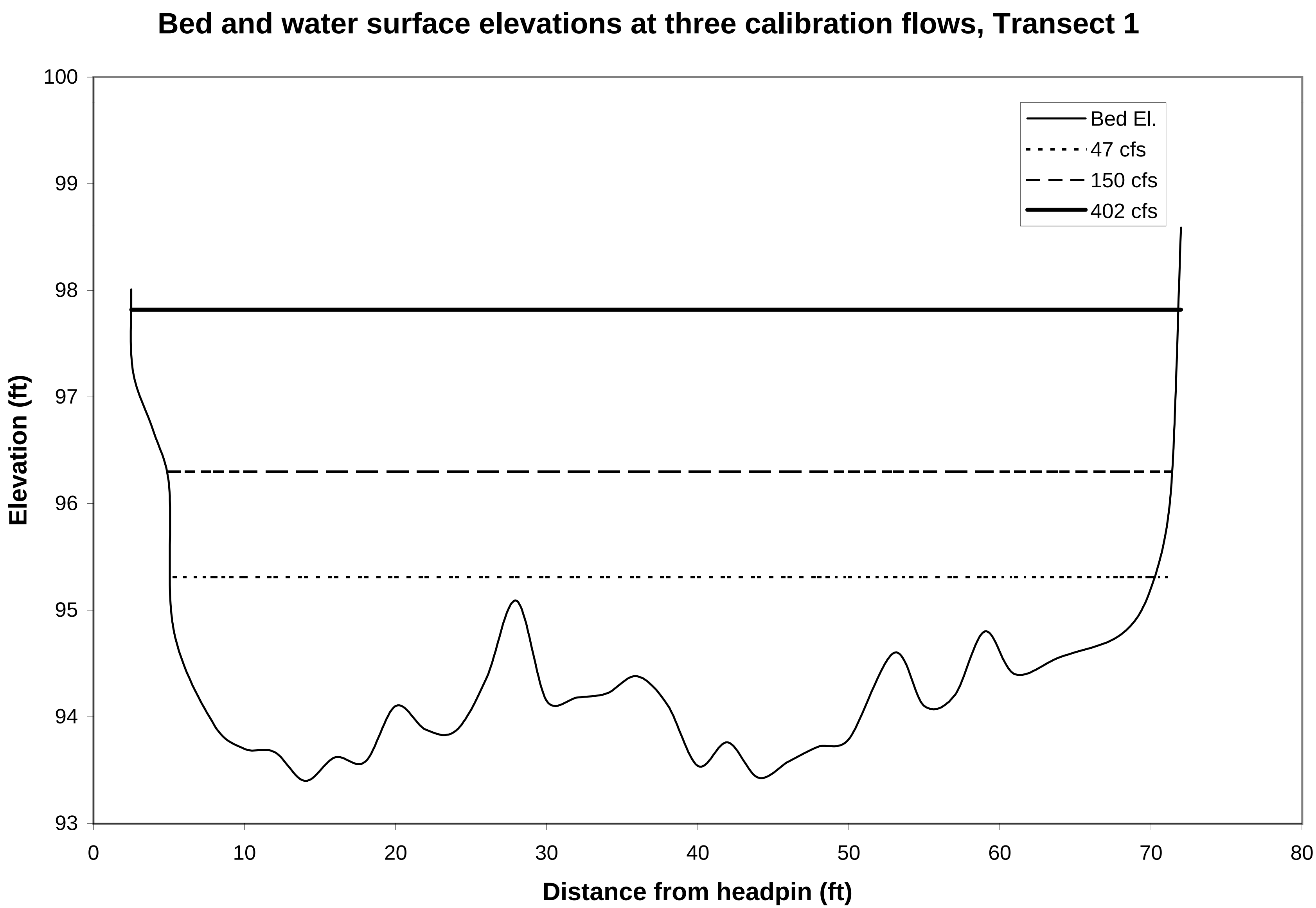
Stream Order	SI
1	0.5
2	0.8
3	1.0
4	1.0

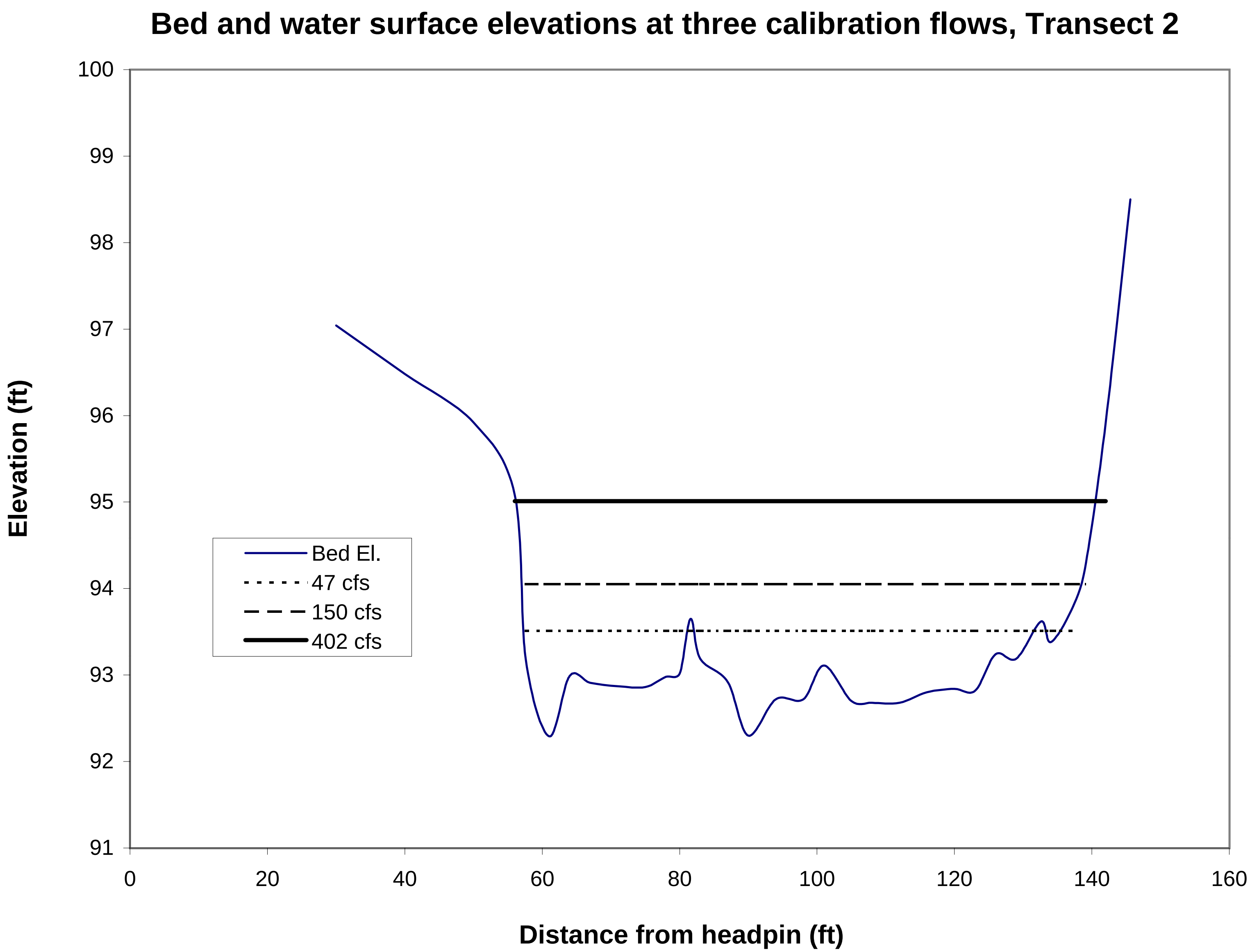
V17: Dominant substrate for spawning and embryo incubation.



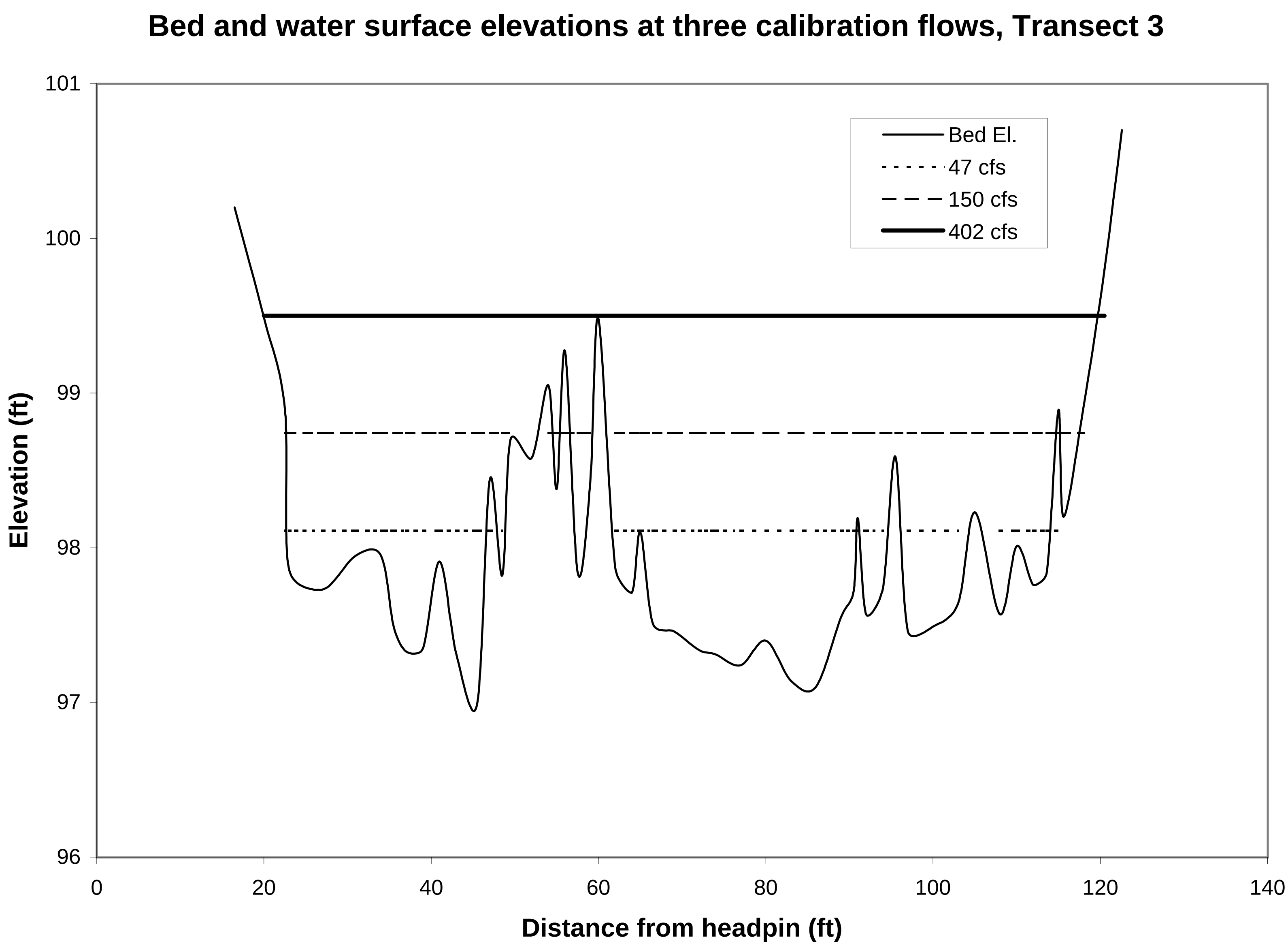
Substrate Code	Substrate Type	Size (mm)	SI
1	Fines	< 0.5	0.00
2	Sand	0.5 - 2.2	0.00
3	Pebble-gravel	> 2.2 - 22.2	0.95
4	Cobble	> 22.2 - 256	1.00
5	Boulder	> 256	0.00

APPENDIX C: STREAM BED AND WATER SURFACE PROFILES OF STUDY TRANSECTS

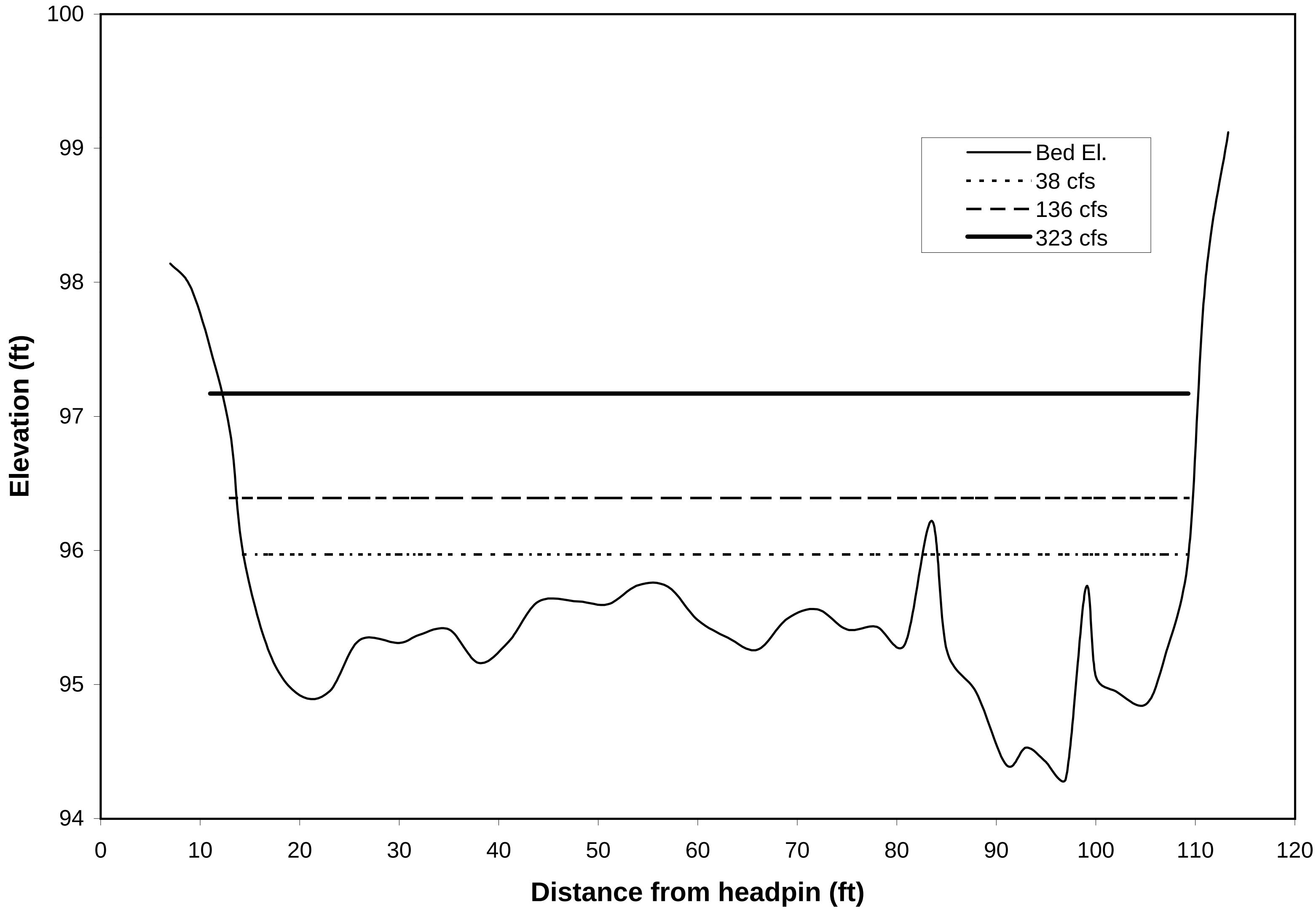

Bed and water surface elevations at three calibration flows, Transect 1
Elevation (ft)
100
99
98
97
96
95
94
93
0
10
20
30
40
50
60
70
80
Distance from headpin (ft)
Bed El.
47 cfs
150 cfs
402 cfs

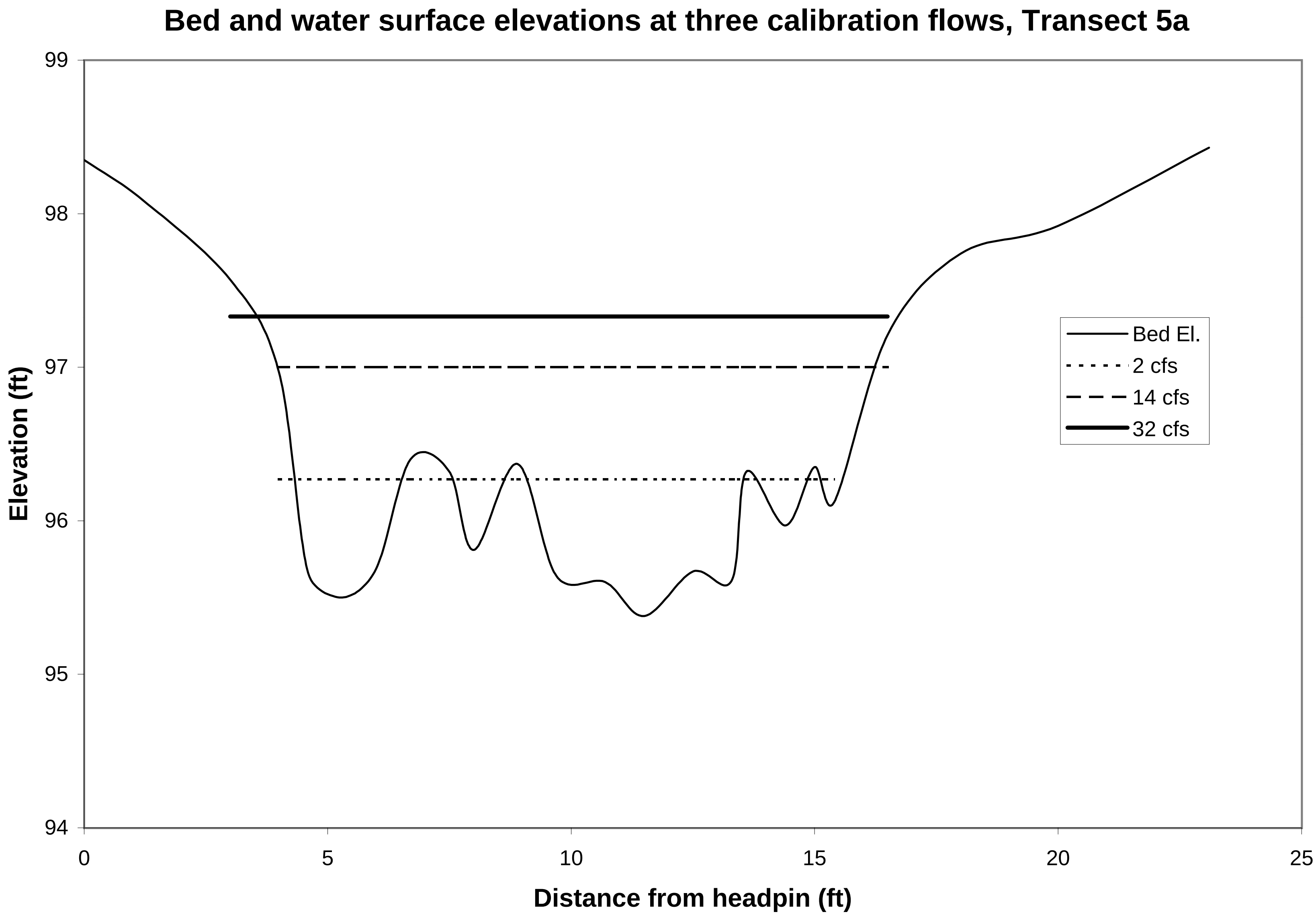


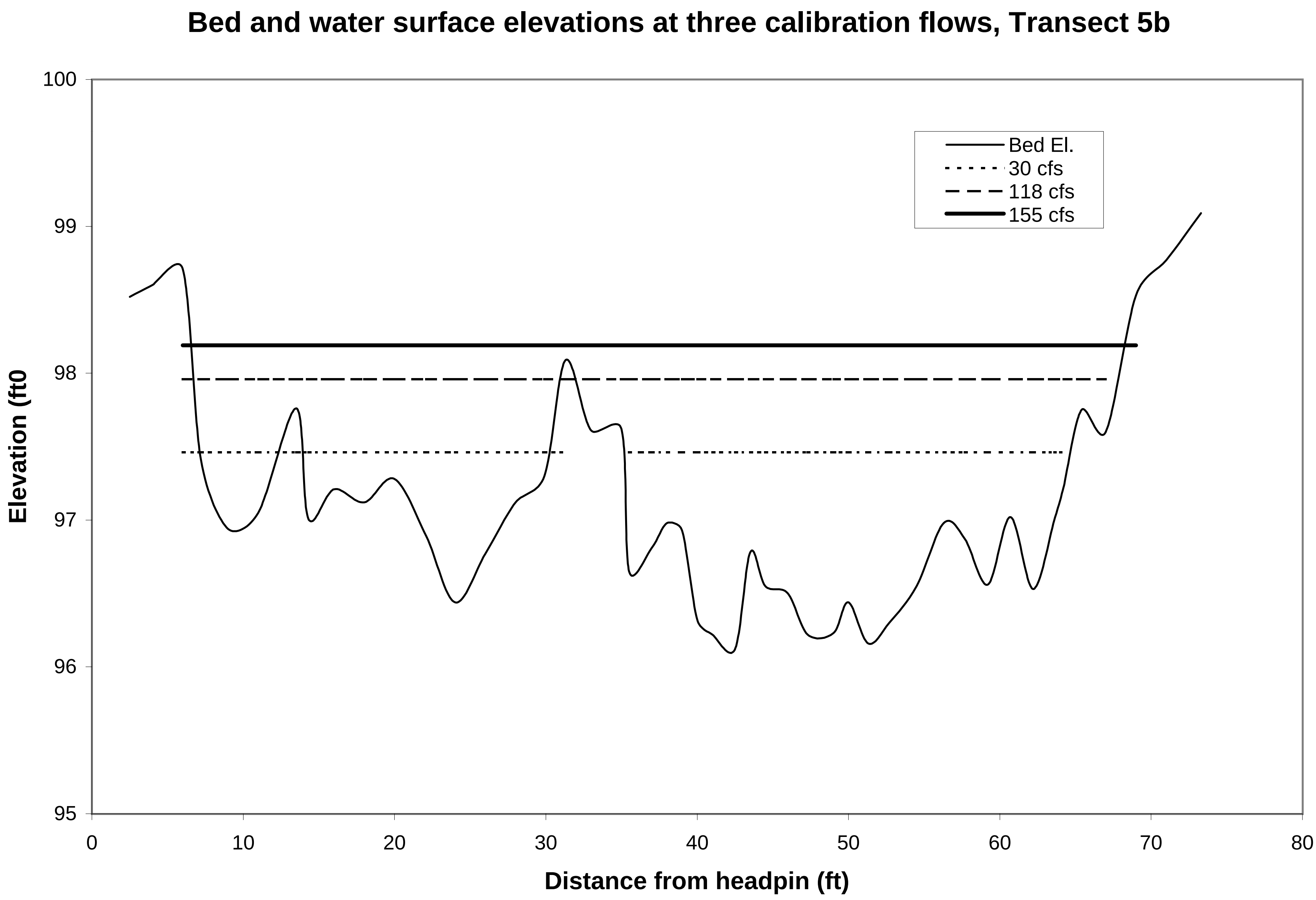
Bed and water surface elevations at three calibration flows, Transect 2
Elevation (ft)
100
99
98
97
96
95
94
93
92
91
0
20
40
60
80
100
120
140
160
Distance from headpin (ft)
Bed El.
47 cfs
150 cfs
402 cfs


Bed and water surface elevations at three calibration flows, Transect 3
Elevation (ft)
101
100
99
98
97
96
0
20
40
60
80
100
120
140
Distance from headpin (ft)
Bed El.
47 cfs
150 cfs
402 cfs

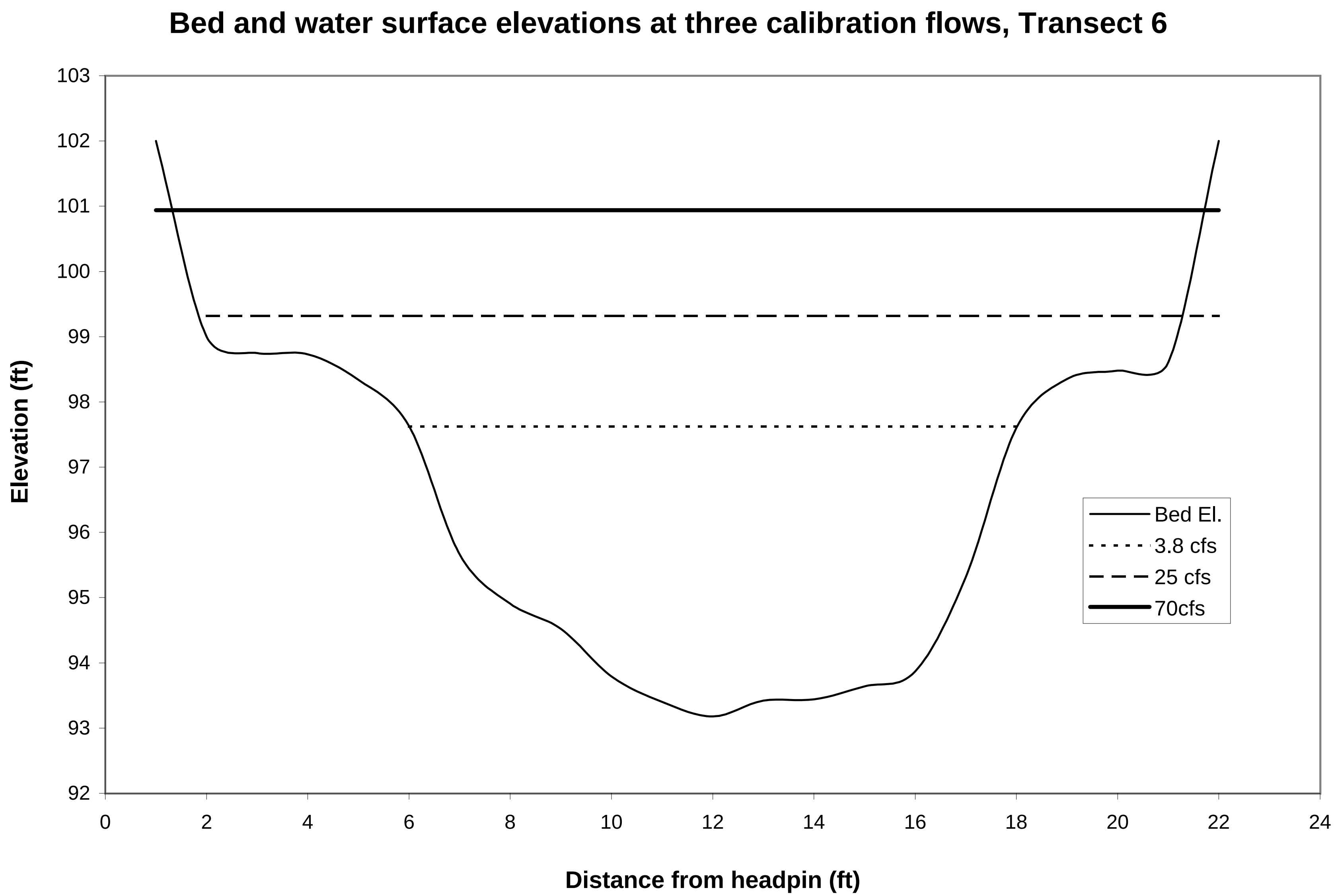
Bed and water surface elevations at three calibration flows, Transect 4



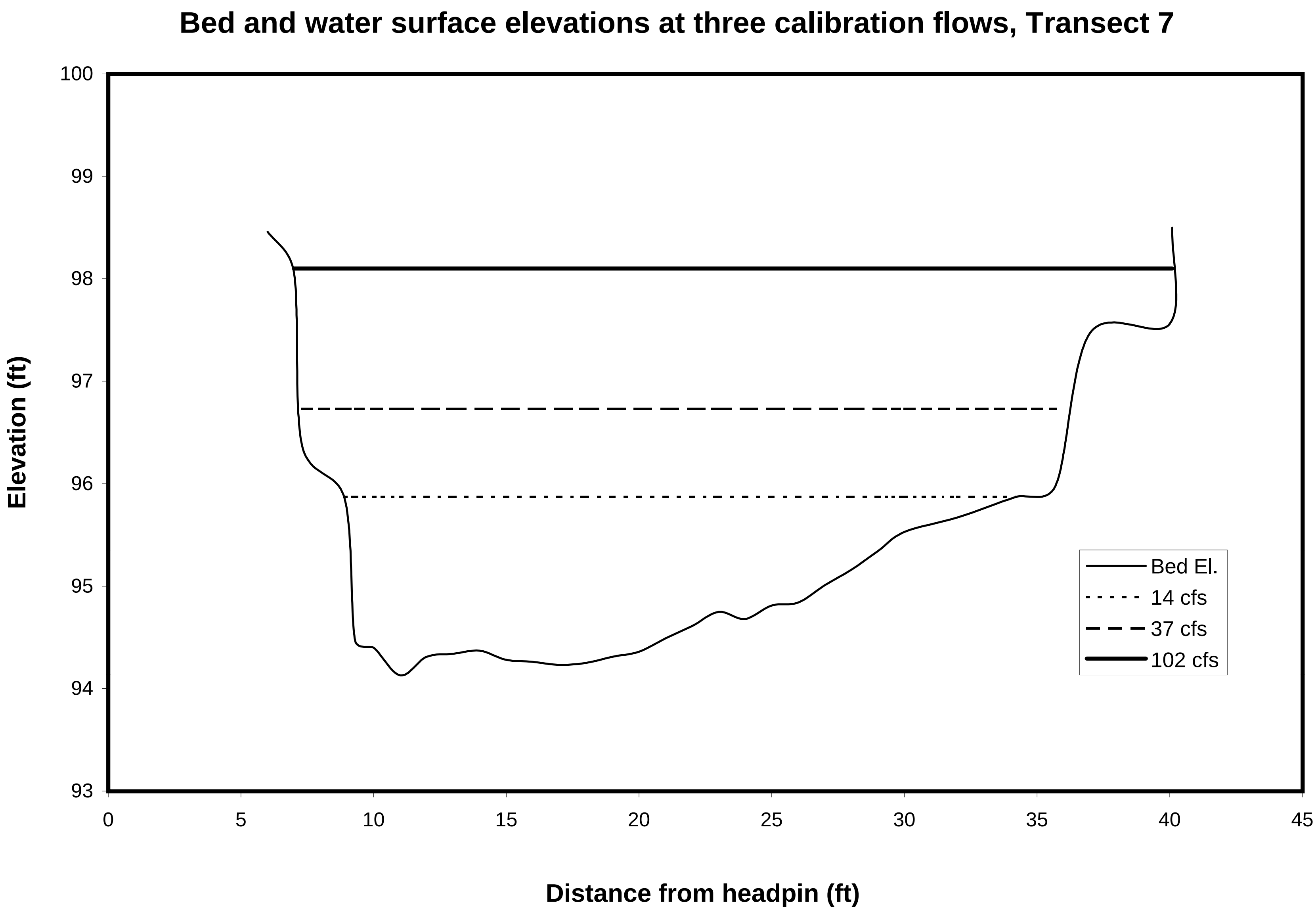

Bed and water surface elevations at three calibration flows, Transect 5a
Elevation (ft)
Distance from headpin (ft)
99
98
97
96
95
94
0
5
10
15
20
25
Bed El.
2 cfs
14 cfs
32 cfs



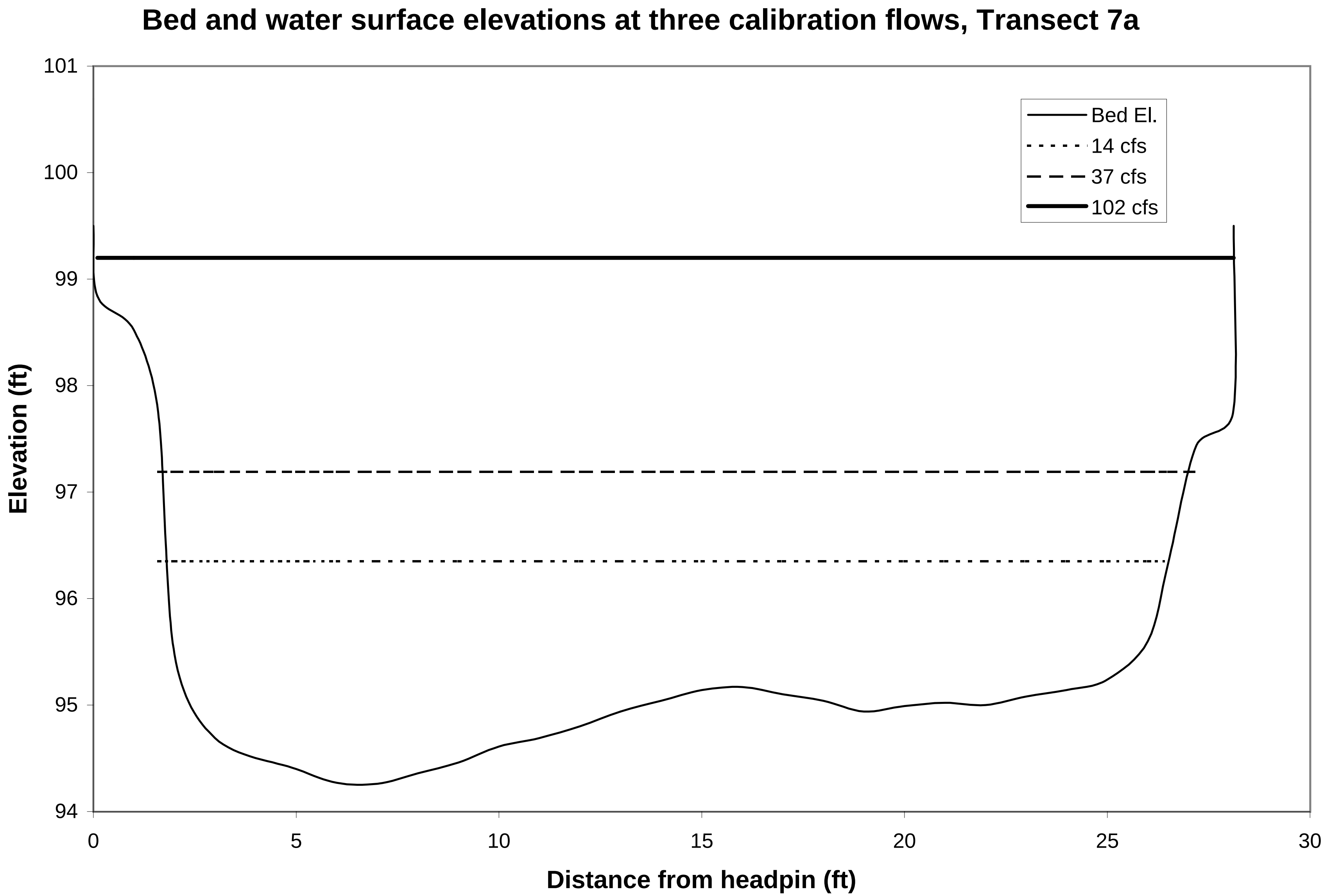
Bed and water surface elevations at three calibration flows, Transect 5b
Elevation (ft0
100
99
98
97
96
95
0
10
20
30
40
50
60
70
80
Distance from headpin (ft)
Bed El.
30 cfs
118 cfs
155 cfs

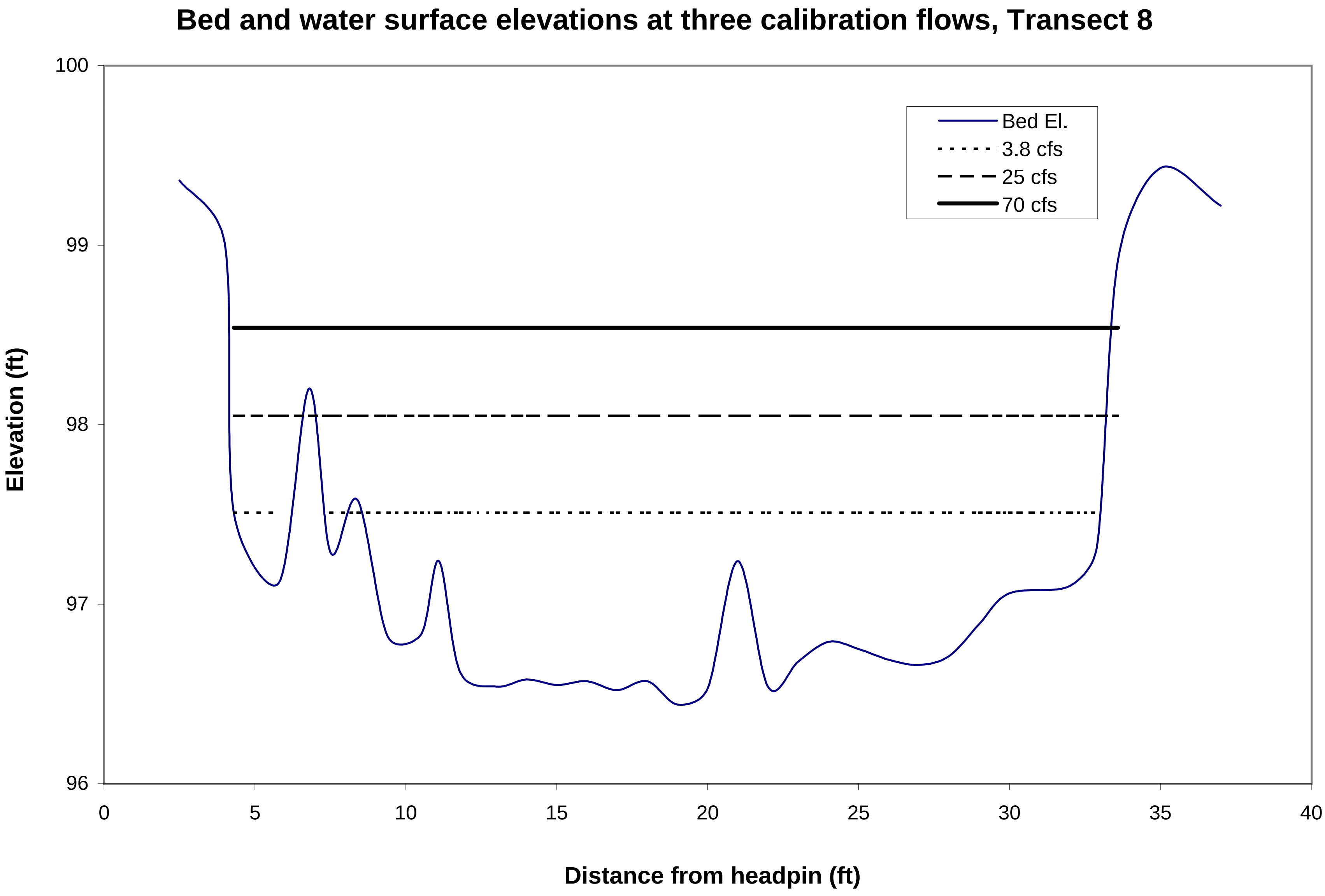


Bed and water surface elevations at three calibration flows, Transect 6
Elevation (ft)
103
102
101
100
99
98
97
96
95
94
93
92
0
2
4
6
8
10
12
14
16
18
20
22
24
Distance from headpin (ft)
Bed El.
3.8 cfs
25 cfs
70cfs



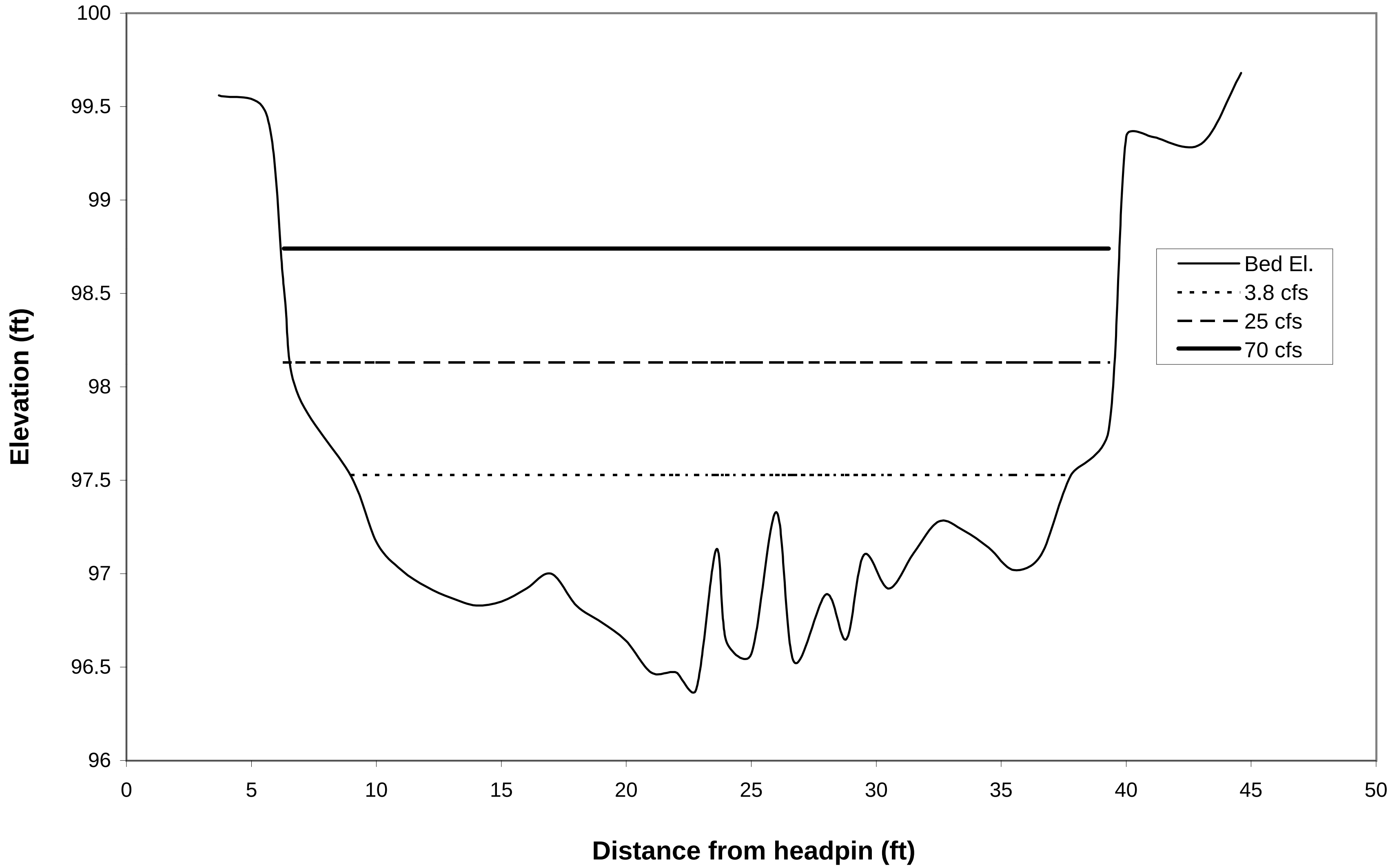
Bed and water surface elevations at three calibration flows, Transect 7
Elevation (ft)
100
99
98
97
96
95
94
93
0
5
10
15
20
25
30
35
40
45
Distance from headpin (ft)
Bed El.
14 cfs
37 cfs
102 cfs


Bed and water surface elevations at three calibration flows, Transect 7a
Bed El.
14 cfs
37 cfs
102 cfs
101
100
99
98
97
96
95
94
Elevation (ft)
0
5
10
15
20
25
30
Distance from headpin (ft)

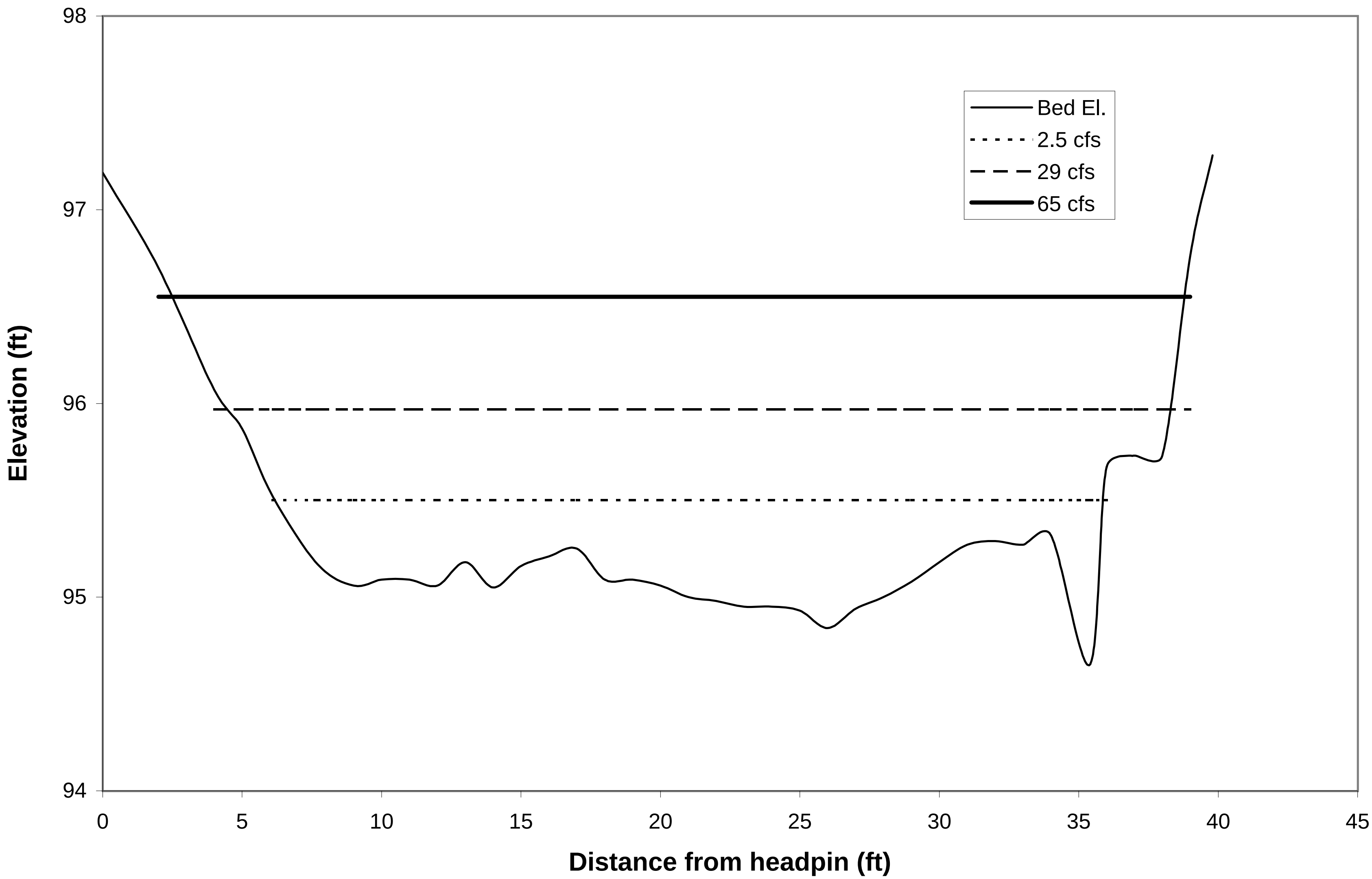


Bed and water surface elevations at three calibration flows, Transect 8
Bed El.
3.8 cfs
25 cfs
70 cfs
Elevation (ft)
100
99
98
97
96
0
5
10
15
20
25
30
35
40
Distance from headpin (ft)

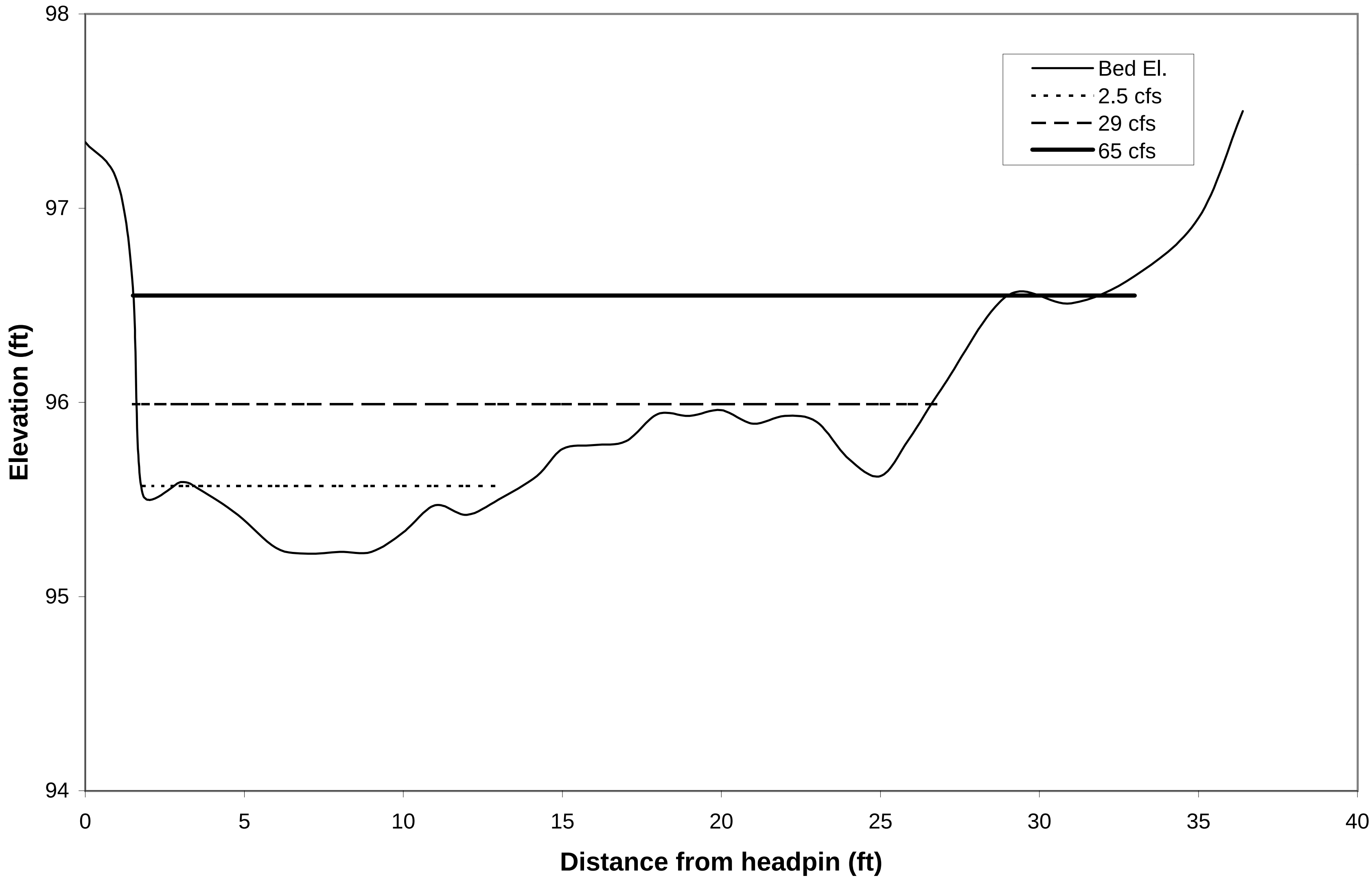
Bed and water surface elevations at three calibration flows, Transect 9

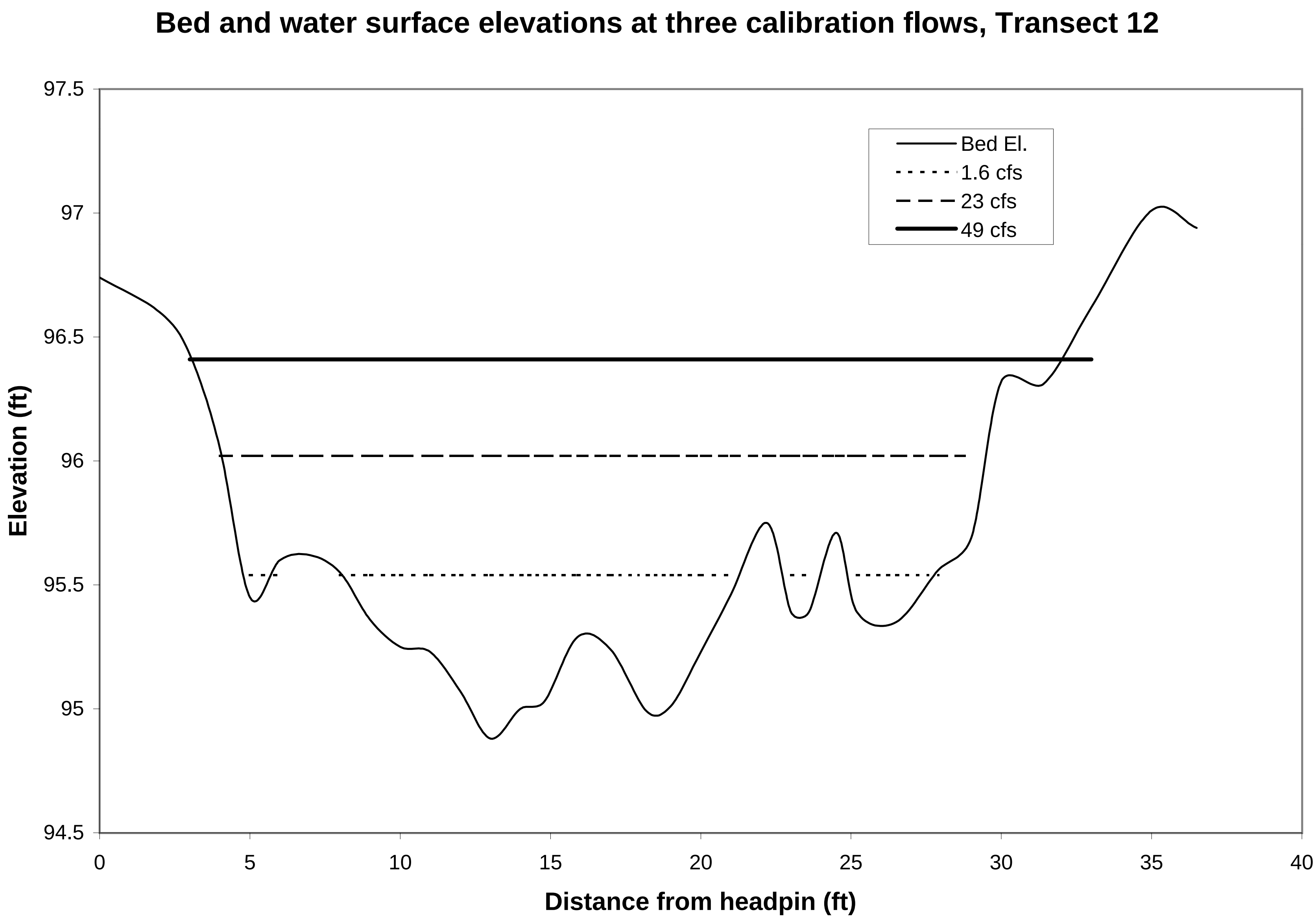


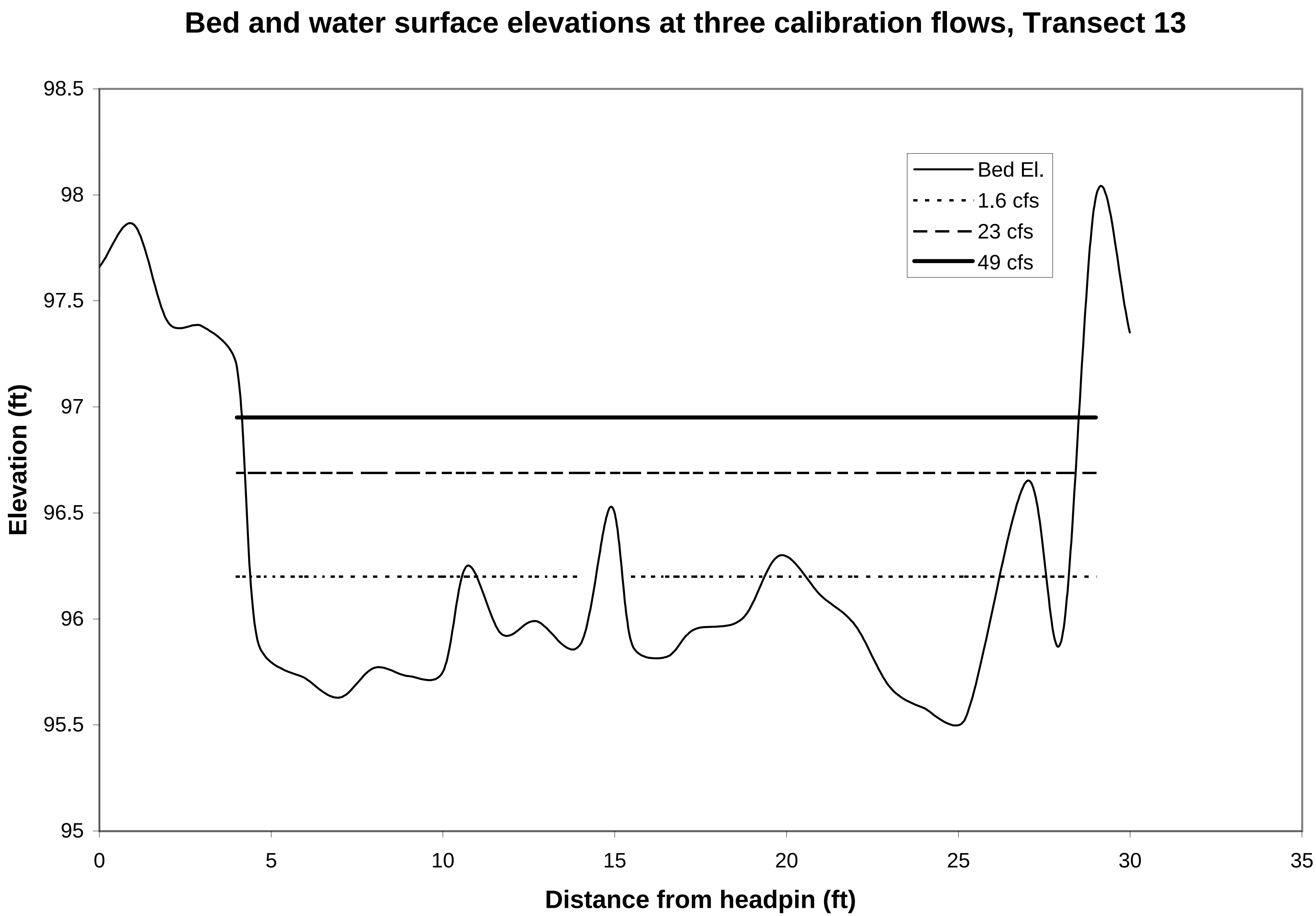
Bed and water surface elevations at three calibration flows, Transect 10



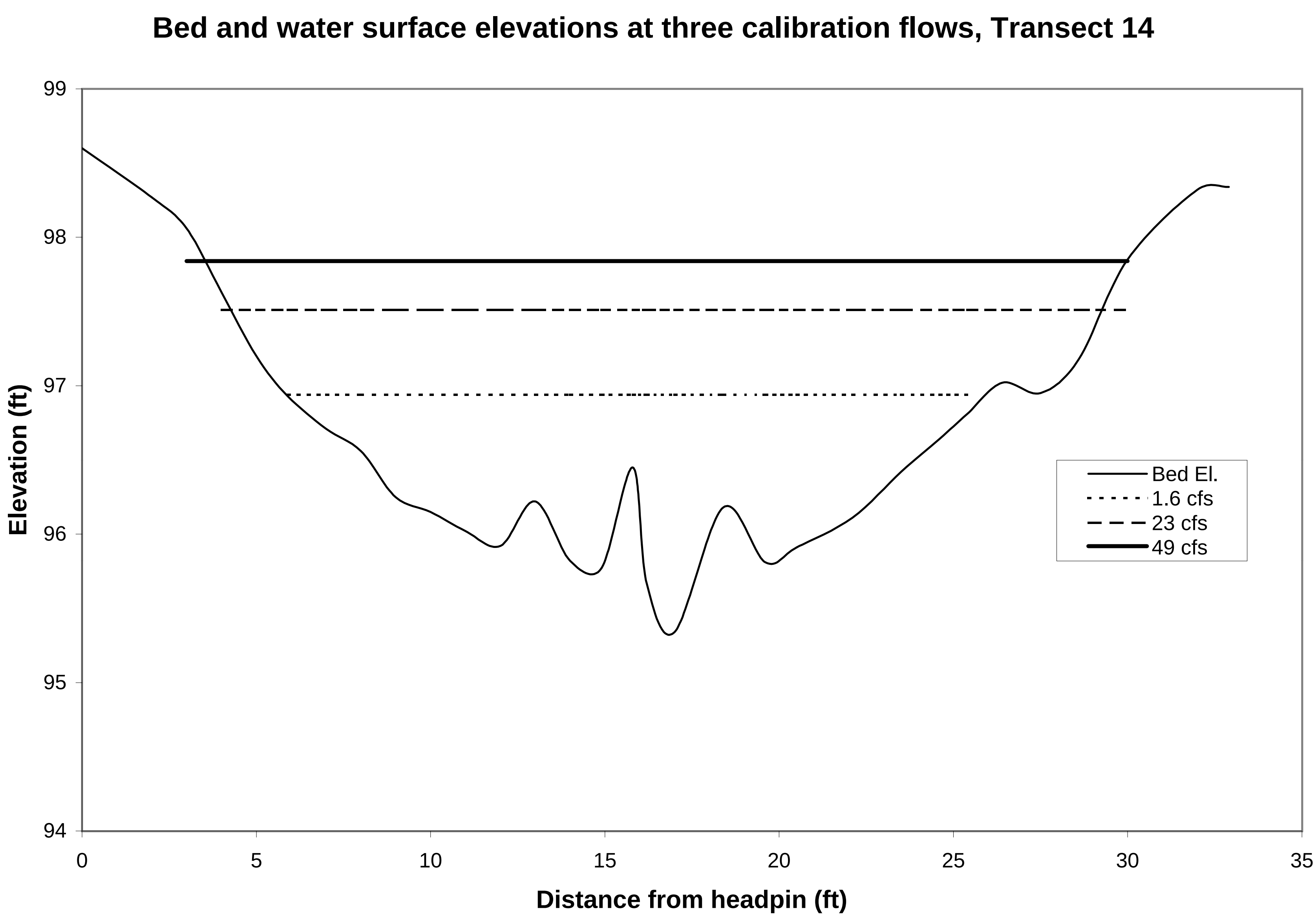
Bed and water surface elevations at three calibration flows, Transect 11




Bed and water surface elevations at three calibration flows, Transect 12
Bed El.
1.6 cfs
23 cfs
49 cfs
97.5
97
96.5
96
95.5
95
94.5
Elevation (ft)
0
5
10
15
20
25
30
35
40
Distance from headpin (ft)



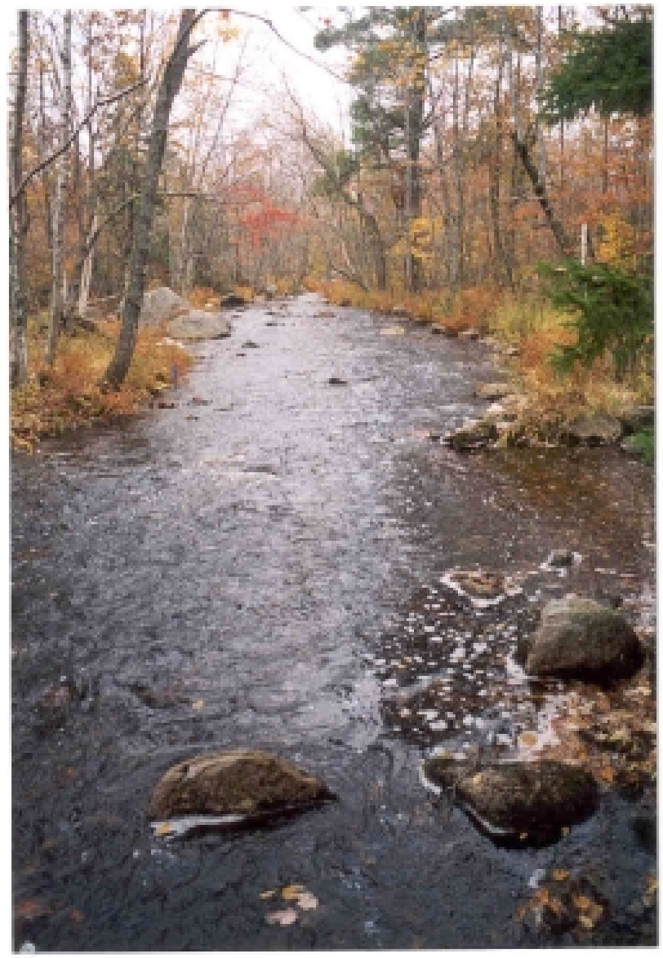
Bed and water surface elevations at three calibration flows, Transect 13
Bed El.
1.6 cfs
23 cfs
49 cfs
98.5
98
97.5
97
96.5
96
95.5
95
Elevation (ft)
0
5
10
15
20
25
30
35
Distance from headpin (ft)


Bed and water surface elevations at three calibration flows, Transect 14
Elevation (ft)
99
98
97
96
95
94
0
5
10
15
20
25
30
35
Distance from headpin (ft)
Bed El.
1.6 cfs
23 cfs
49 cfs

APPENDIX D: PHOTOGRAPHS OF STUDY SITES

Photo Plate 1. Pleasant River IFIM study, view of Reach No. 1 study site. Riffle habitat. October 1998.

View looking downstream from transect 14.



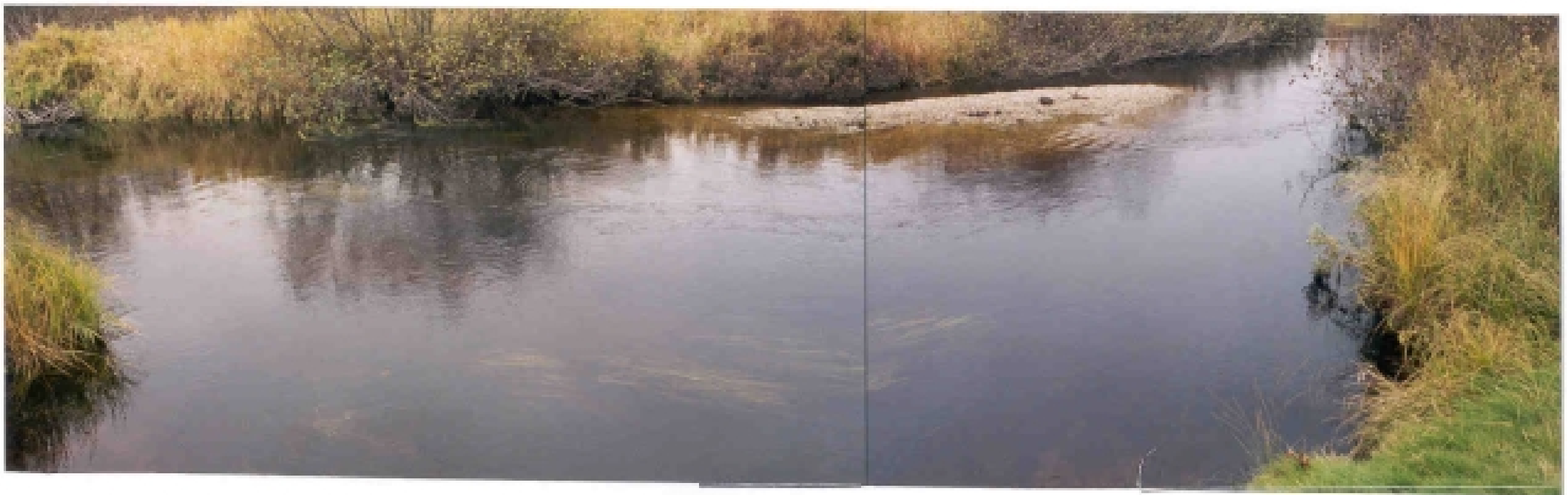
View looking upstream from transect 12

Photo Plate 2. Pleasant River IFIM study, view of Reach No. 2 study sites. Riffle and run habitat. October 1998.

Spawning riffle (transects 10 and 11)

Run (transects 8 and 9)

Photo Plate 3. Pleasant River IFIM study, view of Reach No. 3 study sites. Pea gravel glide habitat.



View looking downstream from transect 7a, October 1998.

Detailed view of grass clumps and substrate, August 1998.

Photo Plate 4. Pleasant River IFIM study, view of Reach No. 3 study sites. Adult holding pool habitat.

Run/pool habitat, at "L Meadow", transect 6, October 1998.

Photo Plate 5. Pleasant River IFIM study, view of Reach No. 4 study site. Riffle habitat. October 1998

Overview of riffle, looking upstream along main channel .

Close-up of transect area (transect 5b)

Photo Plate 6. Pleasant River IFIM study, view of Reach No. 5 study sites. Riffle habitat.

Spawning riffle (Transect 4) , looking from headpin to tailpin, August 1998 .

Mixed substrate riffle, near transects 2 and 3, October 1998.